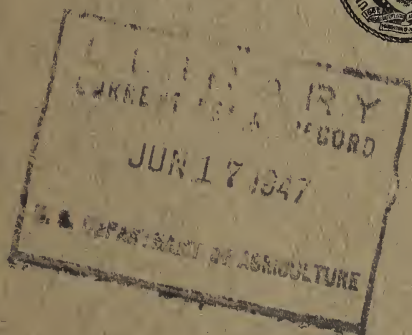


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UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION

REPORT ON
THE AGRICULTURAL EXPERIMENT
STATIONS, 1946



PREPARED BY THE
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REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1946 ¹

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INTRODUCTION—REALIZED AND POTENTIAL VALUES OF STATION RESEARCH

The partial reconversion during 1946 of the State agricultural experiment stations from the emergency status of the war years brought no cessation in the calls for research information. Rather, there was increasing need for the services of the stations due in part to the continuing world-wide demand for food and in part to the realization that more and more research facts will be needed for the maintenance of a permanent and efficient agricultural industry in the days ahead when production again catches up with demand.

The urgent need for more research services to agriculture has long been recognized by the major farm organizations, other groups of citizens, and by many individuals. This resulted after the close of the year in the enactment of the Research and Marketing Act of August 14, 1946, which authorizes under title 1 additional Federal grants for a greatly augmented research program by the State agri-

¹ Submitted in accordance with the requirement that the Secretary of Agriculture shall report to Congress on the work and expenditures of the State agricultural experiment stations established under the Hatch Act of 1887 and supplementary legislation. The period covered is the fiscal year ended June 30, 1946.

cultural experiment stations, for further commodity utilization research by the United States Department of Agriculture, and funds for cooperative research projects by the Department and the stations on regional and national problems. Testimony introduced at the hearings showed that agricultural research has lagged far behind research in other fields and that much additional research is needed to enable agriculture to attain a position in research comparable to that of other great industries.

Although faced during the greater part of the year by continued shortages of research workers and research facilities, the experiment stations made noteworthy contributions to better farming and rural life. The volume of services rendered by them was increased by the end of the year with the return of many former staff members from the armed services. A total of \$7,206,208 of Federal-grant funds was appropriated under the authorizations of the Hatch, Adams, Purnell, and supplementary acts and title 1 of the Bankhead-Jones Act for expenditure by the stations during the year. These funds together with supplementary funds from State sources were used for the support of investigational work on a total of 3,505 specific research projects in fields authorized by the respective acts. There were 507 new and revised projects undertaken during the year. Work was completed on 456 projects, a turnover of about 15 percent of the projects active at the beginning of the year. In addition to the Federal-grant funds, the stations expended a total of \$20,786,854 of funds from non-Federal sources including State appropriations during the year for the complete support of 4,808 non-Federal projects and the partial support of the Federal-grant projects.

An increasing volume of the research work of the stations was carried on cooperatively among groups of States and between the stations and the Department on regional and national problems. The four regional groups of directors gave increasing attention during the year to problems involved in the conduct of cooperative research projects currently active in the separate regions and to the planning of additional cooperative work on the more pressing problems that could best be undertaken through cooperative study. Much of the station research involving cooperation with the Department is conducted under formal memoranda of understanding. A total of 1,168 such memoranda were effective during the year.

Some of the year's progress and results of experiment station research is related by brief examples under the subject matter sections of this report. Many additional items could be cited. Acknowledgment has been made of cooperation with the United States Department of Agriculture in a number of instances. Other cases may have been overlooked. There is so much informal exchange of information and research materials among the stations and between the stations and the Department that any complete acknowledgment of aid would be impractical.

The accumulated benefits of agricultural research run into many millions of dollars annually. Often the results of research cannot be expressed in monetary values. This is true as a rule of research in the social sciences and of findings that contribute to better nutrition and health of humans and to greater comfort and convenience in the home. Some values that have been realized recently are cited in the

several sections of this report. As a rule, the values stated are only those realized in individual States. If extended to larger areas, as many of them have been, the benefits would be materially greater than those shown. In addition to these realized values, many other recent findings have great potential value. Some of these will come into widespread use in the next few years. Some examples of realized and potential values are summarized briefly as follows:

EXAMPLES OF REALIZED AND POTENTIAL VALUES OF AGRICULTURAL RESEARCH

Corn breeding research by the Colorado station has resulted in the planting of hybrid corn on approximately 85 percent of the irrigated corn acreage and 30 percent of the dry-land acreage of the State. In 1945, the value of hybrid seed corn produced by registered growers was \$125,000. Production of irrigated corn has increased over 4 million bushels during the past 4 years, much of the increase being due to the use of hybrid seed.

Connecticut 15, a new, high-yielding variety of shade tobacco developed by the Connecticut (State) station has produced increases of 25 to 50 percent of marketable leaves in commercial growers' fields over other shade tobacco. One grower produced over \$7,000 worth of tobacco per acre. Resistance to root rot and yields of 20 to 25 marketable leaves per plant as compared with 15 to 18 for other varieties account for the increase.

Increased tomato yields amounting to 4,500 tons brought additional returns of \$180,000 to Delaware growers in 1945 who adopted results of Delaware station experiments showing that broadcasting and plowing down 1,200 pounds of 5-10-10 fertilizer before setting the plants, together with closer spacing, gives increased yields of 1 ton per acre.

Sorghum research by the Oklahoma station and the Department has yielded information as to the most satisfactory varieties for grain, forage, and sirup in various parts of Oklahoma, and more productive forage and grain varieties have been developed. The annual value of this research is estimated at \$3,000,000 for the production of grain, \$6,000,000 for forage, and \$1,000,000 for sirup—a total of \$10,000,000.

Citrus pulp has become an important cattle feed in Florida. The production of this feed, moreover, has helped canners of the State in a serious problem of the disposal of cannery waste. Citrus pulp production exceeds 50,000 tons a year valued at \$45 per ton, or a total annual value of \$2,250,000. The research on drying citrus pulp and determining its value for feed was largely done by the Florida station.

Sanford wheat planted on approximately 58 percent of the 1945 wheat acreage of Georgia had an increased value of over \$400,000 to the farmers of the State as compared with the other varieties grown. Since the development and introduction of this high-yielding variety by the Georgia station, more than 10,000 bushels of seed have been distributed to farmers.

New oat varieties with increased yields and high test weight made available to Indiana growers and feeders by the Indiana station produced an estimated increase of 7 million bushels in 1945 valued at \$5,000,000. They helped to replace wheat and corn during the critical feed shortage.

The disease-resistant oat varieties, Tama, Boone, Control, and Marion, developed under the cooperative research program at the

Iowa station, increased the income of Iowa growers an estimated \$23,000,000 in 1943, \$25,000,000 in 1944, and \$34,000,000 in 1945. In these respective years, they were grown on 66, 90, and 98 percent of the oat acreage and produced 32.1 38.7, and 32 percent more than the better old varieties.

Kawvale wheat and Fulton oats, developed by the Kansas station and the Department, saved Kansas farmers an estimated \$10,500,000 during the period 1942 to 1945 due to their resistance to smut. Comanche and Pawnee wheats, developed under the same cooperative program for resistance to smut and rust, were grown on 40,000 and 20,000 Kansas acres in 1945 with increased returns to growers of \$200,000 and \$40,000, respectively, over standard wheats grown in the State. By 1949, Pawnee is expected to be grown on 55 percent of the State wheat acreage increasing the value of the crop by some \$27,000,000, and Comanche on 15 percent with increased income of about \$3,000,000.

Burley tobacco originally was highly susceptible to all common diseases affecting tobacco. The Kentucky station in a breeding program over the past quarter century has developed a succession of improved, disease-resistant varieties with the net result that the value of the Burley crop on a given acreage has been increased about 20 to 30 million dollars annually over the production of the older varieties. Certified seed of two of the improved varieties, Ky. 16 and Ky. 41A, is now grown on about 90 acres by 35 seed producers. A new variety, Ky. 22, with higher resistance and better quality will be grown on 10,000 acres in 1946. Apparently, 70 percent of the Burley growers of the United States are now using varieties developed by the Kentucky station.

The pasture season in Missouri has been increased from 6 to 7½ months by the adoption of research results of the Missouri station. The extra feed obtained from the improved pastures and longer season is equivalent to 37 million bushels of corn and is worth nearly 30 million dollars when corn is valued at 80 cents per bushel.

Seeding of crested wheatgrass on 1 million acres of abandoned cropland in Montana has increased the income of livestock operators about 2 million dollars. The widespread use of this winter-hardy, drought-resistant forage crop from the Siberian plains resulted from cooperative research of the Montana station and the Department. Findings of the Montana station in research on wool shrinkage have increased the sales income of wool growers of the State by at least \$1,500,000 annually.

Cobalt deficiency occurs widely in New Hampshire and has caused heavy losses to the livestock industry for many years. The New Hampshire station identified the cause and showed that the slow starvation of sheep and cattle due to cobalt deficiency can be overcome quickly by administering small amounts of cobalt. One pound of cobalt sulfate is sufficient for 167 cows for 1 year. Now most of the feed manufacturers serving the State include 2 or 3 grams of cobalt sulfate per ton of feed. This small amount adds little or nothing to the cost. Farmers are deriving large benefits through this research.

Sweet corn growers in New Jersey increased their acre profits 100 to 150 dollars in 1945 by using ryania dust for the control of Euro-

pean corn borer. Experiments of the New Jersey station had proved its value against this insect pest. More than 40 tons of this dust, obtained by grinding the dried wood of a tropical plant, *Ryania speciosa*, were sold in the State in 1945 principally for use on sweet corn.

Dairy farmers in New York saved \$487,500 in feed costs and received \$725,000 additional in milk sales in 1946 through the artificial insemination of 65,700 cows. An average of only 34 bulls was used during the year, thus replacing 3,250 bulls costing an average of \$150 each to feed. The increased milk production came about through the use of superior sires. These benefits were made possible by the application of recent results of research by the New York (Cornell) station.

The Massey strawberry, developed cooperatively by the North Carolina station and the Department, yielded North Carolina growers an extra \$124,000 in 1946 because its high quality and attractiveness brought a premium price. The 81,673 crates of Massey sold during a 30-day period for an average of \$11.40 per crate, as compared with \$9.88 per crate for Klondike.

Thirty years of wheat breeding by experiment stations of the hard red spring wheat area and the Department have resulted in the development of a succession of improved varieties, each producing higher yields. In North Dakota during the past 5 years, the increase through use of these varieties is estimated from experiment station yield studies at 192 million bushels worth 240 million dollars, or 48 million dollars per year.

Soybean producers in Ohio were expected to benefit to the extent of \$3,000,000 to \$4,000,000 in 1946 because of the increased value of beans, oil, and meal derived from extensive use of the improved varieties Earliana and Lincoln. According to the Ohio station, 15,000 bushels of certified seed of Earliana and 140,000 of Lincoln produced in the State in 1945 were planted in 1946. Earliana and Lincoln were developed at the Indiana and Illinois stations, respectively, under the station-Department cooperative improvement program.

Use of sprinkler irrigation of hops increased the income of Oregon farmers more than \$690,000 in 1945. Based on Oregon station experiments showing increases of 25 to 40 percent due to irrigation, an estimated 5,000 to 7,000 acres are now under irrigation in the Willamette Valley.

Pear growers of the Hood River Valley increased their average production of marketable Anjou pears from 200 to 300 boxes per acre and their total returns about \$800,000 in 1946 by switching from wettable sulfur spray to Fermate. Earlier Oregon station-Department cooperative experiments showed Fermate to be more effective for pear scab control and less injurious to foliage.

Three examples of the many ways in which South Dakota farmers increased gross returns by applying research results are cited by the South Dakota station as follows: Increased yield of oats through planting of newer varieties—\$16,770,000; saving in feed consumption and increased meat production through adoption of improved feeding practices for cattle, sheep, and swine, including practicable use of soft corn—\$20,200,000; and adoption of improved breeding, feeding, and management practices for poultry—\$1,562,000; a total of \$38,532,000.

The annual income of Tennessee farmers has been increased by some \$13,214,000 through use of improved varieties of barley, corn, oats, and soybeans developed by the Tennessee station with Department cooperation in part. Varieties playing an important role in the expansion of acreage and higher yields are Tennessee Winter 52 and Jackson No. 1 barleys; Neal Paymaster and Jellicorse open-pollinated corns and a Neal Paymaster hybrid; Tennex, Fulwin, and Forkeddeer winter hardy oats; and Ogden and Volstate soybeans.

Texas farmers are benefiting to the extent of some \$30,000,000 annually from use of recently developed root-rot resistant strains of sorghum bred by the Texas station. Commercial rose growers of the Tyler area increased the value of their crop more than \$50,000 in 1945 by dusting with sulfur-copper dust for control of black spot. Ten million rose plants were dusted according to procedures worked out by the Texas station.

Alfalfa seed production, averaging only 60 pounds per acre in Utah in 1945, was increased to 400 pounds in experimental plots of the Utah station and the Department when dusted with DDT to control Lygus bugs. Commercial fields dusted with DDT yielded 200 to 300 pounds of seed. Greatly increased income to alfalfa seed producers is in prospect as a result of this research.

Peanut growers in Virginia are saving \$1.25 to \$1.50 per 85-pound bag in labor costs by using machine-shelled seed and seed treatments developed in Virginia station-regional-Department cooperative investigations. Untreated machine-shelled seed gives poor stands and growers had to use hand-shelled seed before the benefits of seed treatment were discovered. The station estimates a potential saving of \$200,000 annually in labor costs and \$150,000 in value of peanuts eaten by shellers when all of the 150,000 acres of peanuts in Virginia are planted with machine-shelled treated seed.

The cherry industry of West Virginia represents a production of some 3,000 tons in Jefferson and Berkeley counties. Research by the West Virginia station is credited with saving the industry, threatened with destruction by cherry leaf spot, by proving the great superiority of fixed copper sprays or bordeaux mixture over sulfur sprays formerly used by growers. West Virginia growers who sprayed in 1945 according to station recommendations averaged \$1,297 gross sales per acre in the following year. Poorly sprayed orchards averaged only \$504.

RECENT ADVANCES IN ANIMAL PRODUCTION

The broad field of animal production represents a large segment of agriculture in the United States. Approximately one-half of the gross income of American farmers in 1945 came from the sale of livestock and livestock products. Reliable information on sound and economical practices in the feeding, breeding and management of the herds and flocks on the farms and ranches of this country is in great and constant demand. Ways in which the agricultural experiment stations have continued to serve this important branch of our agriculture are indicated in the examples of recent research accomplishments cited in the following paragraphs.

THE ROLE OF FORAGE CROPS IN ANIMAL PRODUCTION

The importance of grasses and legumes in cropping programs designed to maintain or improve the quality of our soils, the possibility of high per acre returns with relatively low labor cost from improved pasture and forage crops and the higher nutritive value of green grasses and legumes and of well-preserved hay and silage all are contributing factors to increasing interest in the improvement of pastures and ranges and the maximum use of roughages in all types of livestock production. Research continues to open the way for extended use of and increased returns from these important feed crops.

Based primarily on findings of the Missouri station regarding establishment, renovation, fertilization, and controlled grazing, development of pasture land in Missouri has reached the stage where it will equal the corn equivalent of 184 million bushels, which exceeds the average corn crop of the State by 31 million bushels. The improvement and development of pasture land has resulted in extending the pasture season from 6 to 7½ months under average Missouri conditions. This means annually an increase in feed available from pastures of approximately 37 million bushels corn equivalent, which is equal to 24 percent of the average corn crop. When corn is worth 80 cents a bushel, this pasture improvement program represents an annual benefit of almost \$30,000,000 to farmers of the State.

Pennsylvania station experiments indicate the financial benefits which may be derived from improving pastures for dairy cattle. Every dollar expended in liming and fertilizing the experimental pasture resulted in the production of almost \$3 worth of additional milk.

Proper pasture management frequently results in high returns with little additional cost involved. For example, grazing experiments on short grass pastures by the Wyoming station gave results indicating the possibility of materially increasing the grazing capacity of such pastures. In these experiments carried through from May 18 to September 18, sheep gains in weight were about 20 percent greater under intensive rotation grazing than where no rotation occurred with no apparent difference in the degree of pasture utilization.

Depletion of pasture and range resources with ensuing conservation problems may result from lease agreements which tend to favor excessively heavy stocking. Conservation of rented pasture might be encouraged by a system of paying a given rate per steer, rather than per acre or per 100 pounds gain which are prevailing practices. This suggestion from the Oklahoma station is based on an analysis of data from grazing tests in the State.

The important role of pasture in reducing feed costs in finishing beef cattle is emphasized in Illinois station findings which showed that in carrying Good to Choice cattle to Choice (AA) carcass condition, 1 acre of good bluegrass in 160 days saved 11 bushels of corn, including that in the silage, 340 pounds of soybean meal, 3 tons of silage, and 1½ ton of clover hay.

A study of the forage requirements of sheep by the Nevada station revealed that a dry ewe ate 12.85 pounds of fresh grass daily, a yearling ewe ate 13.26 pounds daily, an early-weaned lamb ate 12.30 pounds daily, a ewe and her single lamb ate 24.21 pounds daily, and a ewe and

her twin lambs ate 33.30 pounds daily. Thus, for all practical purposes a dry ewe, a yearling ewe, and an early-weaned lamb may be considered as having identical daily forage requirements. A ewe and her single lamb will require twice as much forage as a dry ewe and in the case of a ewe with twin lambs the daily forage requirement will be $2\frac{1}{2}$ times as much as a dry ewe. The results of these tests show that the lamb crop is an important factor to consider in allotting forage for sheep. An estimate of forage requirements for a flock of ewes may be in error by as much as 150 percent if the lamb crop is not taken into consideration.

The possibilities of greater utilization of grazing crops as a means of reducing feed costs for swine and poultry are not generally recognized. Ladino clover pasture will supply approximately one-third of the protein needed by growing pigs, the Pennsylvania station has found. Three lots of 20 pigs each were self-fed a mixture of 90 percent ground corn and 10 percent mixed protein supplement. One lot was on Ladino pasture, one was in dry lot, and the third was fed Ladino soilage. Average daily gains were 1.33, 1.24, and 1.44 pounds at a cost of \$7.88, \$9.49, and \$9.70, respectively. This would credit the 1 acre of Ladino pasture with \$26.47 for 70 days of grazing, or practically 2 cents per pig per day.

Similarly, the Michigan station in a comparison of limited feeding on rape pasture and feeding on a concrete floor for a period of about 100 days found that the pigs on pasture gained significantly faster and at a feed requirement of about 390 pounds per 100 pounds of gain as against 460 pounds of feed per 100 pounds of gain for pigs in dry lot.

Pullets on restricted feeding for 9 weeks with Ladino clover range at the Maine station consumed 20 percent less feed than birds given free choice of feed. At housing time, they weighed about one-third pound less but quickly caught up and their egg production for the first 6 months was the same as the birds on unrestricted feed. The feed hoppers of the restricted group were closed at 5 p. m. and opened at 10 a. m. thus permitting a 7-hour feeding period, and forcing the birds to consume green feed during the cool period in the morning and evening. The information helped Maine poultrymen meet the current shortage of grain feed.

Ladino clover further proved its superiority for poultry range in tests conducted last season by the New Jersey station. Although the actual saving in total feed consumption by use of grass range in comparison with total confinement was insignificant, grass range did save approximately 30 percent in mash consumption. Thus, in addition to maintaining birds in an improved nutritional status, the range effected marked saving in the expensive high-protein mash.

Similarly, Delaware and New York (Cornell) station experiments show that, by providing growing pullets access to good range and restricting the rate of concentrate feeding, marked savings in feed can be made without adversely affecting the rate of growth, maturity, or livability of the birds.

PRODUCTION AND UTILIZATION OF SILAGE AND HAY

Further advances have been made in methods of ensiling feed crops which extend the usefulness of this important method of feed preservation.

The preparation of ear corn silage from immature, frost-damaged corn can be recommended on the basis of experiments by the Iowa station. Corn which contained from 26 to 34 percent moisture in the kernels at the end of October was cut and converted into a satisfactory silage by adding water to the ensiled material to bring the moisture content up to nearly 50 percent. Such silage was efficiently utilized by using it as the main ration for feeder steers for a period of 113 days, followed by a finishing period of 30 days on shelled corn and regular corn silage. At prices prevailing for feed and cattle during the 1945-46 season, the ear corn silage was worth an estimated \$72 per acre as compared with \$73.50 per acre for normal shelled corn and \$82.50 per acre for regular corn silage.

The possibility of utilizing corn silage in relatively large amounts for fattening steers has been demonstrated in Illinois station trials. Corn silage full fed without additional corn had no influence on the visible marbling of beef, contrary to common opinion. When fed for equal gains and to a Good grade finish, Good grade yearling feeder cattle fed a full feed of corn silage with 3 to 4 pounds of legume hay and 1 pound of soybean meal per head daily after 100 days, required only 65 to 80 percent as much corn (including that in silage) as cattle fed one-third to one-half feed of silage and two-thirds of a full feed of shelled corn.

In repeated trials at the Mississippi station, unrea-treated silage continued to show a slight advantage in palatability and surpassed untreated silage in maintaining weights of mature beef cows and 3-year-old heifers. The treated silage contained more protein and less carotene and moisture than untreated silage. Urea at the rate of 10 pounds per ton added to silage at silo-filling time was found to be a satisfactory substitute for a protein supplement in wintering rations for beef cattle.

Surplus or cull potatoes can be successfully ensiled in combination with other feed crops according to Colorado station findings. Potato-corn fodder silage and potato-alfalfa hay silage each produced faster gains in fattening steers over a 196-day feeding period and at lower feed costs than corn silage. Also, dehydrated potato meal was almost as palatable as ground corn and produced slightly higher gains and the steers finished out nicely.

Timothy silage preserved with 72 pounds of molasses per ton proved about equal to good corn silage in economy of milk and butterfat production in a New Jersey station experiment. Timothy silage preserved with 200 pounds of ground barley per ton of green material produced a palatable and well preserved silage although it was significantly lower than the molasses-timothy or corn silage in economy of milk production. The effective use of timothy as silage is an important phase in the development of a grassland type of farming which is proving desirable in many sections of the Northeast.

Studies at the Michigan station have shown that corn silage contains some, as yet, undetermined factor which has a distinct milk-stimulating influence when fed to dairy cows, thus illustrating that unidentified nutrient factors frequently play a dominant role in determining the total nutritive value of a feedstuff.

Proper combination of silage and hay generally permits maximum utilization of roughages in animal feeding.

Experiments extending over a period of years, conducted cooperatively by the Western Washington Experiment Station and the Department, proved that where abundant hay and silage of good quality are available heifers can be raised on hay and silage alone from yearling age through the first three lactation periods without detriment to skeletal growth or breeding efficiency, when compared with companions of similar age raised on feed with a high protein-grain supplement. This is important information for dairymen facing shortages of concentrates. Where available, a limited grain supplement proved to be an advantage in that milk production was increased 20 to 25 percent.

Saving of grain effected by limited feeding in accordance with procedures developed by the Kansas station demonstrated that under present conditions satisfactory beef can be produced from feeding a one-third grain ration instead of a full feed. Greater dependence is placed on silage and hay in this new feeding regime. The saving per steer amounts to 1,200 pounds of grain worth \$24 at current prices. It is estimated that 200,000 grain-fed cattle are marketed from Kansas each year. General adoption of this new method, therefore, would result currently in a saving of close to \$5,000,000 annually.

Similarly, deferred grain feeding and physical balance studies at the Kansas station have resulted in a method of finishing lambs utilizing relatively large amounts of roughage and limited amounts of grain. Based on a number of years of experimental work, this method of feeding produces gains at a saving of \$1.63 per 100 pounds compared to the older methods of feeding. This method of feeding has been widely adopted by Kansas feeders and based on a conservative estimate of 30,000,000 pounds of fat lamb produced in the State annually, this would result in a financial return of \$489,000. In addition, it is conservatively estimated that 2 percent of the death loss is prevented by this method of feeding. This would result in a saving of 1,260,000 pounds of fat lamb, and if valued at 15 cents a pound would produce \$189,000, making a total resulting from this system of feeding of \$678,000.

Getting the maximum return from cured forages during the current feed shortage and high feed prices continued to be the objective of many stations. On this problem, the South Dakota station reported that in terms of feeding value 1 ton of early-cut western wheatgrass hay is worth 1 ton of late-cut western wheatgrass hay plus 300 to 400 pounds of soybean meal or cottonseed meal. At present feed prices this amounts to \$9 to \$12 a ton greater value for early-cut hay over late-cut hay.

Many thousands of tons of meadow hay are harvested annually in Nevada for hand-feeding during the winter months to cattle. A comparison by the Nevada station of hays harvested on July 10 and September 10 showed the early-cut hay to be practically twice as rich in protein and phosphorus as the late-cut hay. The significance of these differences in nutritive value was forcefully shown in winter feeding trials with steers in which those fed the early-cut hay consumed an average of 15.7 pounds of hay daily and made an average daily gain of 1.5 pounds over a period of 100 days, while comparable steers fed the late-cut hay consumed 11.9 pounds daily but showed an average net loss of weight of 2 pounds per head over the same period.

At the present time in Nevada hay is usually valued by the ton, depending on supply and demand with little or no consideration given to the feeding value of the hay. It is evident that the feeding value varies greatly and the variation is a direct result of the time when the hay is harvested.

Digestion experiments at the Virginia station showed that with proper supplementation of such hays as timothy, the whole dairy ration can provide as high a percentage of total digestible nutrients as is usually obtained when alfalfa hays of average quality are fed. This timothy hay, however, must be of good early-cut quality. It must be supplemented with a grain ration which furnishes in the whole timothy ration as much digestible protein as the whole alfalfa ration, and must contain enough of a mineral mixture to provide amply for calcium and phosphorus deficiencies in the timothy hay. Fortification of the ration with irradiated yeast or other carrier of vitamins A and D also appears to be essential.

A third and final trial recently completed at the Oklahoma station confirms results of the preceding two tests in showing that good peanut hay is equal to good alfalfa hay for dairy cows. A summary of the three trials shows no significant differences between the two rations in maintenance of body weights, yield of 4 percent fat-corrected milk or amounts of feed required to produce 100 pounds of 4 percent milk. The small differences which were found were all slightly in favor of the peanut hay ration. This finding has great potential value in view of the now extensive peanut producing industry throughout the South.

Tests were carried out by the New York (Cornell) station to study diurnal variations in yield and composition of alfalfa hay. The alfalfa hay cut in the evening showed a small advantage in yield. The evening samples were materially higher in sugar and starch than were the morning samples, showing an advantage of combined sugars and starch of 22 and 12 percent for oven-dried and field-dried samples, respectively. The potential gains to agriculture thus indicated are tremendous.

The feeding of hay to dairy cows on good bluegrass pasture gave returns in terms of increased milk production far in excess of the normal market value of the hay according to Ohio station findings. These results were obtained on improved pastures under a system of rotational pasturing, where to all appearances adequate grazing was available. Furthermore, the hay-fed cows continued to produce at a higher level after the pasture season than cows which had not received the hay. These findings emphasize the importance of supplying supplementary feed for the producing dairy herd on pasture even during periods when lush grazing is available.

INCREASING EFFECTIVENESS OF CONCENTRATED FEEDS

Further evidence of the value of including corncobs in the rations of various classes of livestock has been obtained by the Ohio station. In digestibility trials with Hereford steer calves comparing rations to which varying amounts of corncobs had been added, the nutritive value of the corncobs averaged more than 51 pounds of total digestible nutrients per 100 pounds of the cobs, or about 64 percent as valuable as the grain itself for energy or fattening purposes. In eight feed lot comparisons the corn replacement value of the corncobs averaged

62 percent. There were, however, fluctuations in cob utilization, the partial cause of which is believed related to microbiological digestion in the alimentary canal of the animal.

In experiments with growing chickens and with laying hens, where corn-and-cob meal was substituted for ground shelled corn in the ration, the Ohio station found little difference in mortality but, in general, a slightly lower rate of growth from the corn-and-cob meal, whereas the average feed consumption and the pounds of feed per pound of final live weight of the birds favored the corn-and-cob meal. Egg production on the corn-and-cob meal ration averaged 52 percent per bird as compared with 55 percent on the ground shelled corn ration. A noticeably better condition of the plumage and little or no feather picking or cannibalism were observed among layers receiving the corn-and-cob meal. These factors may prove of far greater worth than the disadvantage of slightly lower egg production and body weight.

In Ohio station trials with Holstein cows, a simple grain mixture containing ground ear corn and reinforced with extra soybean oil meal yielded results within about 2 percent as satisfactory as a comparable mixture containing ground shelled corn, showing that the common practice of feeding ground ear corn to dairy cows is fully justified.

The Montana station found that alfalfa hay, cereal grains, and dried beet pulp constitute satisfactory cattle fattening rations. On the basis of the experimental results, two rations with alfalfa hay are recommended for fattening steer calves: One consists of ground barley, dried molasses beet pulp, and linseed cake (45-45-10); the other, of ground wheat and dried molasses beet pulp (50-50).

Dried sweetpotatoes proved a satisfactory concentrate for fattening steer calves in trials at the Oklahoma station. There was little difference in the rate of gain or amount of concentrate required per unit of gain in comparable groups receiving corn and dried sweetpotatoes, respectively. Because of the low protein content of sweetpotatoes, as well as the relatively low digestibility of sweetpotato protein, approximately 40 percent more cottonseed meal was required to supplement the sweetpotato ration than the corn ration. Dried sweet potatoes were estimated to be about 95 percent as valuable as corn, pound for pound.

Rations with a fat content as low as 0.5 percent were found by the Indiana station to be less efficient for weight gains in pigs than those containing 5 percent or more. However, rations containing 5 percent or more of a softening fat such as soybean oil produced a softer body fat which was reflected in carcasses lacking desirable firmness for the meat trade. For the economical production of desirable pork, 2 to 3 percent of fat in the ration appeared optimal.

In the manufacture of peanut butter, the hearts (embryos) and skins are removed before grinding the nuts. In 2-year trials of these byproducts as part of the rations for pigs, the Georgia station found the hearts to have about the same feeding value as whole peanuts. When slaughtered at the end of the tests, the fat of an occasional animal proved to be soft. When fed only 20 percent of the ration, however, the chances of soft pork production would probably be very small; if corn is used as the principal carbohydrate, it is advisable to

feed the hearts as only 15 percent of the ration. The peanut skins proved unpalatable, even when added to the ration in finely ground form; thus, in spite of their fair oil content, the skins are practically worthless as a feedstuff for pigs.

PROTEIN FEEDING

Urea as a partial replacement for cottonseed meal in beef cattle rations has given satisfactory results in a series of experiments at the Oklahoma station. Yearling heifers were wintered as satisfactorily on pellets containing 25 percent of their protein (nitrogen) in the form of urea and the balance from cottonseed meal as when all the protein was from cottonseed meal. In one trial, pellets containing 25 to 50 percent urea nitrogen proved equal to cottonseed meal when fed as a supplement to corn and hay for fattening steers and in a second trial results were only slightly less favorable to the urea. Also, in metabolism experiments, pellets containing up to 50 percent urea nitrogen proved a satisfactory protein supplement when added to corn and prairie hay. The possibility of using urea in this manner to extend vegetable protein for feeding beef cattle is highly significant in the face of an acute protein deficiency for normal livestock feeding.

In a study of the comparative value of various protein concentrates given to western ewe and wether lambs under feed-lot conditions, the New York (Cornell) station found linseed meal, soybean oil meal, whole soybeans, and corn gluten meal to be about equal as supplements in the ration. The lambs consumed a higher proportion of the roughage offered and were easier to keep on full feed with the linseed meal, which also proved slightly superior to distillers' corn dried grains (dark) and brewers' dried grains. Optimum growth and fattening were obtained when enough linseed meal was fed in the ration to provide an air-dry protein content of 10 to 10.5 percent. Lambs fed urea nitrogen as a substitute for all of the linseed-meal nitrogen were difficult to keep on feed and gave unsatisfactory feed-lot performance. As a substitute for two-thirds of the nitrogen, urea failed to show any improvement over the results from a ration containing the same amount of linseed meal but no urea.

In investigations to determine how locally grown feeds of oats, barley, and wheat can be successfully utilized in the Matanuska Valley, the Alaska station found that cows fed additional protein in their concentrate ration produced significantly more milk and butterfat than those fed entirely on locally grown grains with oat-pea silage and oat-pea hay. The station has recommended that dairy farmers of this area supplement their locally grown grains with purchased linseed meal, soybean meal, or other high protein supplements. The practice is justified both on the basis of total production and on the cost per unit despite the relatively high cost of such imported feedstuffs.

In trials by the New Hampshire station on wood yeast fed to dry cows, no abnormal physiological effects from the ration were observed. Insofar as it affects the kidneys, yeast protein evidently could be fed as safely as other common feedstuffs; it not only proved exceptionally high in protein content but excelled in digestibility all protein feeds tried except those of animal origin.

Safflower, the new oil crop which has given excellent yields in drier sections of Nebraska, has proved useful in feeding sheep and cattle and for wintering calves in experiments conducted by the Nebraska station. Safflower meal, the product left after the oil has been extracted, gave as good as or slightly better results in these trials than soybean oil meal.

Various combinations of meat meal and ground cull peas in the protein-mineral supplement fed free-choice with rolled wheat to fattening pigs in dry-lot tests by the Idaho station led to the conclusion that the cull peas make an excellent protein supplement for fattening pigs if properly balanced with a small amount of meat meal. On the other hand, field peas proved unsatisfactory as the only protein concentrate in the ration.

In further trials by the Idaho station with feeder pigs, cull peas were used advantageously to replace part of the grain ration in the dry lot, thus making larger quantities of wheat available for human consumption. Since cull peas are also palatable, they thus provide an economical and practical constituent of the ration for fattening pigs.

According to experiments by the Illinois station, corn and wheat can be stored at 78° to 82° F. for 2 to 3 years—either ground or as whole kernels—without appreciable deterioration as to protein value in nutrition. Soybeans, however, unless heated prior to storage as in oil extraction by the expeller process, undergo a considerable loss in the digestibility and biological value of their proteins.

In feeding experiments with rats, the Kentucky station found cold-pressed tobacco-seed meal to be deficient in lysine; however, when supplemented with casein, lactalbumin, skim-milk powder, or lysine, good growth was obtained. In fact, the biological value of the oil meal protein, when supplemented with lysine, was approximately that of milk proteins. Because of its relatively high net protein value, tobacco-seed oil meal deserves consideration as a source of dietary protein.

Shark meal proved practically equal to roller-process dried skim milk as a major protein supplement in rations both of swine and poultry according to Florida station findings. No fishy flavor was imparted to the meat as a result of feeding the shark meal to either class of animals.

Yeast was shown by the Indiana station to be higher in nutritive value than distillers' dried solubles as the only source of protein; it also effectively supplemented the solubles and corn separately or in combination. Biological tests with rats indicated the solubles to be inadequate as the only source of protein or as a protein supplement because of their deficiencies in lysine and tryptophan; furthermore, chemical studies revealed them to be considerably lower in lysine and tryptophan, as well as in less available forms, than in yeast.

In poultry feeding trials by the West Virginia station, it was shown that for egg production a mash in which soybean meal furnished the only source of supplementary protein gave satisfactory results when balanced with the necessary vitamins and minerals. Some animal protein should, however, be included in starting and hatching rations, a minimum of about 2.5 percent apparently being needed. For rapid growth, the animal protein should be supplied in part by fish meal.

Satisfactory results were obtained by the Louisiana station with laying rations containing only one protein ingredient, such as shrimp meals, cottonseed meal, peanut meal, or soybean meal, when the hens had access to good green feed crops—ryegrass and white clover for winter-spring grazing and lespedeza and Bermuda and carpet grass for summer-fall grazing. A conservative estimate is that provision of good poultry pastures to Louisiana flocks will increase egg production by 3 dozen eggs per hen, particularly when fed simple rations. On a State-wide basis this would increase the farm income from eggs by more than 3 million dollars.

Both the cooking of the meal and additions of ferrous sulfate to the ration containing cottonseed meal reduced the number of inedible eggs following storage according to work by the Alabama station. Inedible storage eggs obtained from a cooked cottonseed meal-ferrous sulfate ration varied from 0 to 29 percent, depending on how much free gossypol the original cottonseed meal contained. Cottonseed meal produced by an improved commercial extraction method and containing a very low amount (0.005 percent) of free gossypol produced no yolk discoloration in storage eggs, even when fed without added iron.

The Nebraska station has discovered an enzyme-inhibiting substance in raw soybeans which prevents full utilization of soybean protein by chicks. The destruction of this deleterious principle by heat resulted in adequate soybean utilization in the rations. This finding should prove of great value to poultry feeders; it also shows the possibility that other natural feedstuffs may contain similar inhibitors which can reduce their nutritive value.

Soybean meal and corn gluten meal were found by the Wisconsin station to be satisfactory as the sole high protein feeds in chick starting rations, when supplemented with 3 percent fish solubles. The overheating of extracted soybean flakes resulted in diminished nutritive value, but marked improvement followed the addition of casein or essential amino acids along with the known vitamins. Application of too much heat evidently is as detrimental as too little in the processing of soybean meal.

Soybean meal as the only source of protein in the chick starting ration produced heavier birds than peanut meal or wheat-germ meal, and they in turn were better than cottonseed meal, corn gluten feed, or linseed meal, which was definitely unsatisfactory according to feeding trials by the New York (Cornell) station. All rations classified as Good also included fish meal. Mortality was usually lowest and gains were more economical on rations showing the most favorable growth.

The nutritive value of the proteins of raw soybean oil meal, as determined by total gain in weight and by gain per gram of protein consumed by New Hampshire chicks, was found by the Washington station to be increased by autoclaving, the availability of the methionine and cystine or of the organic sulfur in the raw meal being increased by the heat treatment. Addition of methionine increased the growth and feed efficiency of all the diets, even though it was retained in the treated meal to a much greater extent than the cystine.

Experiments by the Washington station proved also that excellent results in egg production can be secured from hens fed untoasted soy-

bean oil meal manufactured by the solvent process. Toasted soybean oil meal also gave good egg production; in fact, when supplemented with fish meal, it gave as good production as straight fish meal along with excellent hatchability.

Protein shortages have directed attention to sources not ordinarily thought of as useful in rations for chicks. One of these, amounting to more than 10,000 tons annually, is the waste from hatcheries. The Missouri station found that when dried incubator offal was fed at levels of 3 or 6 percent of the total ration, it proved a satisfactory substitute for meat scrap or soybean oil meal.

In experiments by the South Dakota station, millet was successfully substituted for corn in a chick starter ration using soybean oil meal, provided the vitamin A was maintained at a satisfactory level.

Since Alaska pea meal had been proved deficient in methionine for satisfactory growth responses in chicks, the supplemental value of several proteins was investigated by the Idaho station. For maximum growth, additional methionine was found to be required in all the rations tried; there were, however, wide differences among the various protein sources in supplying it. Meat meals from rendering plants or packing houses gave unsatisfactory gains, but with added methionine the responses were equal to those obtainable with methionine-supplemented fish meal. Among the materials tested, herring fish meal, casein, and dried milk were excellent supplements to the pea meal, but a combination of pea meal and soybean meal—used even at the high levels in a chick starter—proved deficient in methionine.

A lobster refuse meal gave satisfactory growth when fed to chicks during a 12-week period at the Rhode Island station. This product was substituted at a level of 4 percent of the animal protein in the regular experiment station ration, which carried a protein content of 19.27 percent. Because of its high calcium content, the meal also replaced 1 percent of the limestone in the regular feed. These results suggest that considerable quantities of lobster refuse, now largely waste material, could be advantageously substituted for some of the animal protein in poultry rations.

Tung meal subjected to different heat treatments and sieving before feeding at different levels in a soybean meal ration was found by the Florida station to cause a severe diarrhea in all chicks receiving it, as well as heavy mortality at the higher levels. Even when heated at 11.5 pounds pressure and 115.5° C., the tung meal proved as toxic as the raw product.

In feeding trials conducted by the Hawaii station with Rhode Island chicks fed to 6 weeks of age, the inclusion of approximately 30 percent processed garbage gave satisfactory results when soybean meal or fish meal supplied the remainder of the protein; garbage up to 20 percent also proved satisfactory with meat meal.

MEETING THE VITAMIN REQUIREMENTS

Providing adequate vitamins in the ration of young hand-fed calves is an important factor in maintaining health and vigor.

Vitamin A and niacin supplementation proved desirable in calf feeding when the vitamin A intake is marginal according to Wisconsin station findings. Ten thousand International Units per calf per day

were found to be marginal, while 25,000 I. U. from commercial sources proved adequate for the newborn colostrum-free calf. The niacin effect was negligible in the presence of adequate vitamin A, and biotin was apparently unnecessary. Calves could be raised on vitamin-fortified skim milk from birth, survival being greater on summer than on winter skim milk, presumably due to nutritive factors in the milk associated with grass in the ration.

The importance of supplying an adequate amount of carotene or vitamin A in the ration of dairy cows during late stages of gestation has been clearly demonstrated by separate experiments of the Kansas and New York (Cornell) stations. Each has shown that the vitamin A stored in the newborn calf can be materially enhanced by providing the mother with liberal amounts of carotene or vitamin A during the last few weeks of pregnancy. The importance of quickly attaining a high vitamin-A level in the blood stream on the well-being of the young calf has been established in earlier experiments.

As commonly practiced, dairy calves are allowed to nurse their dams for a few days, but the colostrum not consumed is ordinarily milked out and discarded. Recent studies by the Ohio station have shown that colostrum has special nutritive values and that when portions not consumed by nursing are milked out, saved, and fed to calves, beneficial results are obtained through more rapid growth and building up of vitamin A reserves. Universal adoption of this practice would result in less difficulty with calf ailments, reduce calf mortality, and release an estimated 150,000,000 pounds of whole milk annually for human use.

The Wisconsin station has shown that the vitamin A concentration of colostrum varies as much as sevenfold among first-calf heifers fed and managed alike; subsequent freshening reduced the vitamin A by 50 percent, and extreme reductions have been encountered in the sixth freshening. It is evident that farmers should improve the colostrum milk by more careful feeding of rations high in carotene, including roughage.

In an investigation by the Pennsylvania station of the utilization and excretion of ingested ascorbic acid by dairy cows, it was revealed that either in crystalline form or as part of a natural product it is rapidly destroyed in the rumen. The apparent independence of the cow for ascorbic acid in the ration was reflected by normal concentrations in the blood and milk in spite of a low ascorbic acid intake over prolonged periods. Furthermore, the intake of ascorbic acid on low ascorbic acid rations was exceeded by the combined output in the milk and urine.

Vitamin deficiencies occur frequently in practical swine rations. A basal ration for pigs composed of ground yellow corn, expeller soybean meal, dehydrated alfalfa meal, fortified cod-liver oil, and minerals was found by the Illinois station to be nutritionally inadequate for gestation and lactation of sows under dry-lot conditions. Addition of sardine condensed fish solubles, however, effectively corrected the deficiencies, the fish solubles apparently providing supplementary nutrients—probably vitaminlike—which were required for satisfactory growth, gestation, and lactation. Fall-seeded rye pasture also proved an excellent source of the needed supplementary nutrients.

In feeding trials with pigs involving purified rations, conducted by the Washington station, the poorest gains in weight were made and more feed was required per unit of gain on thiamine-deficient rations. Both thiamine and riboflavin were much more efficiently utilized from natural than from purified grain rations; there was also a greater destruction of these vitamins in the intestinal tract when they were fed in the crystalline form than when given in natural feeds. The deposition of thiamine in the meat was related to the amount in the ration, the loin and ham usually having the highest concentration.

Pork provides one of the richest natural sources of thiamine for man, the Pennsylvania station has found, and its nutritive value can be further enhanced through use of feeds that are rich in this vitamin. Thiamine storage in the muscle tissues of growing pigs is much lower under high-protein rations. This relationship is less evident, however, at high levels of thiamine intake. At common feeding levels around 19 percent of the ingested thiamine is stored in the tissues, but storage may be greatly increased by raising the thiamine content of the rations.

A cold environment was observed by the Illinois station to increase the requirement of pigs for riboflavin, to decrease that for thiamine, and probably to decrease the requirement for niacin.

Investigations of many factors involved in meeting the vitamin requirements of poultry continue to be a productive field of research.

Chick starting mash, when stored in an unheated room in cotton bags, was found by the Pennsylvania station to suffer no measurable loss in carotene or vitamin A in 6 weeks; however, losses of 27 and 21 percent were suffered in 12 weeks and of 52 and 56 percent in 24 weeks. The carotene was supplied by alfalfa meal and the vitamin A by fish oil. On the basis of these results, a chick starter—typified by the mixture here—should retain most of its biological potency during 6 weeks of storage. A 25-percent margin of safety should be sufficient if the feed is to be utilized within 2 to 3 months, but if it is to be stored longer the margin of safety should be increased. Losses in biological potency of feeds may result in the failure of any poultry-raising project.

According to researches by the Connecticut (Storrs) station, the vitamin A requirements of turkey poults are considerably higher than those previously recommended. This station found the minimum requirements for normal growth to 8 weeks of age to be 1,000 International Units per 100 grams of the diet. The 550 I. U. per 100 grams recommended by the National Research Council is stated to include a margin of safety of 66 percent. If a similar margin is provided for the station's minimum of 1,000 I. U., the allowance would be approximately three times that of the Council's recommendation, or 1,660 I. U. per 100 grams. Provitamin A from dried cereal grass and vitamin A from cod-liver oil were utilized equally well, unit for unit, in the experiments reported.

In trials of supplements for distillers' byproducts in poultry breeding diets, the Massachusetts station obtained excellent hatchability results with a ration containing 20 percent of dried distillers' grains with solubles and as little as 1.25 percent of redfish meal as the only animal protein supplement; good results were also obtained with 2.5 percent of meat scraps in the total ration. Very poor hatchability was

obtained, however, with all diets not containing some marine or other animal portein concentrates, though there was no indication that such concentrates were essential for egg production, palability or efficiency of the feed, maintenance of body weight, or livability.

Recent studies by the California station have shown that condensed fish solubles improve growth on corn-soybean meal rations because of factors other than riboflavin; a butyl fermentation product also proved almost as effective a supplement. When some of the corn and soybean meal were replaced by wheat and sardine meal, however, the fish solubles were not nearly so effective as the fermentation product. These results indicate that use of fish solubles in the California type of ration (where wheat and fish meals are used) is not so effective as in a midwestern type of ration.

Soybean oil meal supplemented with crystalline riboflavin produced as satisfactory growth for chicks as did rations using riboflavin carriers such as dried milk, dried whey yeast, or dehydrated alfalfa leaf meal, according to results from the Missouri station. Rations depending on meat scraps as a source of riboflavin resulted in a feed cost of 10.65 cents per pound of gain; on alfalfa, 9.17; on dried milk, 9.18; on yeast, 9.29; and on 25 percent soybean oil meal and crystalline riboflavin, 7.81 cents per pound of gain.

Chick requirements of riboflavin per 100 grams of ration for optimum growth to 4 weeks were 275-325 micrograms as compared with the 325-375 micrograms required by turkey poults in feeding trials by the California station. Moreover, less riboflavin was required by the chick to prevent curled-toe paralysis than the amount needed for optimum growth. In turkey poults, biotin deficiency caused dermatitis and mortality and suboptimum levels of riboflavin resulted in perosis, which, however, was prevented by higher levels of this vitamin.

From assays of eggs laid by individual hens carried over several months on rations containing various levels of riboflavin, the Idaho station found that all individuals responded to an increase in riboflavin intake up to a certain level by producing eggs higher in the content of this vitamin—an important finding in relation to egg quality as a food. It was further revealed that about 8 days are required for the hens to produce eggs of higher or lower riboflavin content on shifting the vitamin level in the feed.

Nearly all of the 10-day-old chicks fed by the Connecticut (Storrs) station on a diet containing over 76 percent of ground yellow corn developed perosis, along with the usual poor feathering under high-corn rations; in similar chicks fed the same ration supplemented adequately with crystalline vitamins of the B complex—particularly niacin—there was normal growth and complete protection from these deficiency symptoms.

In feeding trials with chicks by the Texas station it was revealed that the amount of pantothenic acid in the egg depends definitely on the amount in the ration of the hen, and that there is no significant difference between the content of this vitamin in the egg and in the newly hatched chick.

The pyridoxine requirement of Single-Comb White Leghorn laying and breeding hens was found by the Wisconsin station to approximate 2.0 milligrams per kilogram of ration. A diet deficient in

pyridoxine fed to mature fowls resulted in loss of appetite and rapid drop in body weight, egg production, and hatchability.

In an investigation of promising sources of B-complex vitamins for poultry rations by the Colorado station, assays of the dry rumen contents of steers revealed, for each 100 grams, 1,000 micrograms of thiamine, 1,200 of riboflavin, 4,300 of niacin, and 4,900 of pantothenic acid. The average dried rumen contents furnished about four times the requirement of riboflavin for the growing chick and breeder and eight times that for the layer; as to pantothenic acid, it furnished about four times the amount needed for the growing chick and breeder and six times that required for the layer. Dried rumen contents of sheep, as well as cattle, were found to contain large amounts of B-complex vitamins. It is estimated that approximately 65,000 tons of solid matter from the rumens of slaughtered cattle are available annually which could be processed into a concentrate rich in the vitamin B complex for incorporation in animal rations.

The distribution of folic acid—a recently identified member of the vitamin-B complex essential to poultry—in common feed ingredients has been investigated by the Maryland station. By use of a chick assay procedure devised by the station, it was found that the common cereals (corn, barley, oats, and wheat), fish meal, and dried milk by-products are relatively low in this vitamin; cottonseed meal, rye, wheat bran, and tankage contained somewhat more; and soybean oil meal, alfalfa leaf meal, alfalfa meal, and fermentation solubles proved to be good sources of folic acid. Dried brewers' yeast and dried liver were also excellent sources of this factor. Since many of the most commonly used feed ingredients are low in folic acid, it seems likely that the level of this vitamin may be a critical factor in certain rations for chicks reared under confinement; knowledge as to its distribution should therefore prove valuable in properly formulating efficient poultry mashes.

The folic acid requirements of chicks for normal growth, feathering, and hemoglobin formation as determined by the New York (Cornell) station using purified diets containing preformed folic acid were, for survival to 6 weeks of age, approximately 25 micrograms per 100 grams of feed; for growth and hemoglobin formation at 4 weeks of age, 45 micrograms; for growth at 6 weeks, 45 micrograms, but for hemoglobin formation at 6 weeks, 35 micrograms; and for feathering at 6 weeks of age, not less than 55 micrograms per 100 grams of diet.

The reduced growth, poor feathering, and low hemoglobin and hematocrit values consistently obtained by the Wisconsin station in feeding a purified basal ration to chicks were prevented by adding 25 micrograms of synthetic folic acid per 100 grams of ration thus providing a lead as to the quantitative requirements of chickens for this factor. Further studies by the Wisconsin station of the effects of dietary constituents upon the activity of synthetic folic acid in chick nutrition showed, however, that no definite requirement for this substance can be established because the response to a given amount depends on the type of ration used. Folic acid produced the least response with high-fat diets or diets containing glucose, sucrose, or starch as the sole carbohydrate, and the best response with diets containing high protein, low fat, or corn meal and dextrin as to the carbohydrates.

In experiments by the Missouri station, turkey poultts developed a spastic type of cervical paralysis on rations severely deficient in vitamin B₆ but containing reasonable amounts of all other vitamins known to be required. The poultts examined had a lower than normal red cell volume, but none were markedly anemic. Remission of the symptoms was obtained by administering crystalline vitamin B₆.

Turkey poultts fed by the Maryland station on a highly purified diet containing all necessary nutrients except niacin grew poorly and developed certain deficiency symptoms such as inflammation of the mouth, diarrhea, low consumption and poor efficiency of feed, and poor feathering; furthermore, perosis also occurred in spite of ample manganese, choline, and biotin in the diets. All symptoms were prevented by adding 3 to 5 milligrams of niacin per 100 grams of ration, though higher levels might be needed for optimum growth.

Corn grits constituting 40 percent of a purified ration fed to chicks by the Wisconsin station had a deleterious effect on growth at three different protein levels. This inhibitory effect of the grits was completely counteracted, however, by adding niacin to the ration.

The results of experiments by the Washington station show both choline and betaine in the diet of turkey poultts to be effective in reducing the incidence of perosis though neither completely prevented it. Choline was slightly the more effective in preventing perosis but was ineffective in promoting growth. Addition of gelatin increased the incidence of perosis, depressed growth, and reduced the perosis-preventive properties of betaine. These findings indicate that gelatin contains a factor which interferes with the biological synthesis of choline. From a consideration of all known factors, it appears that a precursor may be required for the biological synthesis of choline from betaine by the turkey and that gelatin contains a factor which inhibits the process.

Similarly in studies by the New York (Cornell) station, gelatin added to a simplified ration of natural ingredients interfered markedly with the antiperotic properties of betaine and yeast but had only a slightly unfavorable effect on the antiperotic properties of choline.

MINERAL DEFICIENCIES

Mineral deficiencies frequently become limiting factors in the efficient utilization of rations by different classes of farm animals, as illustrated by the following examples:

In investigating the phosphorus requirements of ewes for pregnancy and lactation, the Idaho station found that 3.5 to 4 pounds of good quality alfalfa hay (0.19–0.22 percent phosphorus) daily provide enough for the pregnant animal; for the lactating ewe, however, rations containing slightly more (0.23 percent) are needed. Ewes should be wintered during gestation on range forage or roughage containing at least 0.16 percent phosphorus; after lambing, the addition of 1 pound or more of grain to the alfalfa-salt ration will supply sufficient phosphorus.

In comparative experiments by the Minnesota station with steamed bonemeal and rock phosphate from which the fluorine had been removed—used as supplements to phosphorus-deficient rations for dairy cattle—no significant differences between the two were observed, either as to the availability of their phosphorus or their palatability; the gains in weight were slightly larger, however, on the bonemeal,

The outstanding results obtained by the New Hampshire station in quickly overcoming extreme emaciation in cattle and sheep by administering small amounts of cobalt has resulted in the inclusion of this element in the rations for these ruminants supplied by most of the feed manufacturers serving the State. Moreover, the 2 or 3 grams of cobalt sulfate per ton of feed required to correct the deficiency adds little or nothing to the cost; 1 pound of the chemical is sufficient for 167 cows for a year. Tolerance studies by the station showed that bovines can consume 30 milligrams of cobalt sulfate per 100 pounds body weight per day over a considerable period without harmful effects; this far exceeds the amounts added to the feed. The finding that clover contains more cobalt than timothy lends further support to the efforts toward increasing legume production. The station has proved the widespread occurrence of this deficiency throughout most of the State, where it has caused heavy losses to the livestock industry over many years.

Finding that only a very small percentage of ingested cobalt is absorbed from the intestine of the cow and that much of this is quickly eliminated, the Florida station concludes that small amounts of this element should be supplied either continuously or at brief intervals to cattle on deficient range.

A mineral formula developed by the Wisconsin station has greatly reduced the problems of anemia and parasites in the northern sheep area of this State; it includes copper, cobalt, iron, iodine, and manganese, but cobalt was shown to be the ingredient most needed. Dairy cattle in certain areas also responded favorably to this combination.

Use of vitamin D at the rate of 88,000 A. O. A. C. chick units per 100 pounds of mash and vitamin A at 66,000 U. S. P. units per 100 pounds resulted in increased production, lowered cost per dozen eggs, greater percentage of eggshell, increased size of eggs, and increased hatchability, according to Alaska station research on calcium deficiency in laying hens. These supplements reduced the cost of producing eggs from 51.6 to 31.6 cents per dozen.

Feeding trials by the Connecticut (Storrs) station with sodium acid phosphate, tricalcium phosphate, and bonemeal for growing chicks revealed that the phosphorus of all three supplements was readily and equally available for bone calcification, that growth was very similar on all three, and that 0.45 percent available phosphorus in the diet will support excellent growth and bone calcification.

Within certain limits, an interrelationship among calcium, phosphorus, and vitamin D was observed by the Washington station in diets fed to turkey poults; changing the level of any one of them appeared to alter the requirements of the others for optimum growth and calcification. The levels of calcium and phosphorus seemed to exert a greater influence than the ratio between them; best results were obtained at phosphorus levels of 1 percent and calcium levels of 2 to 3 percent.

Vitamin D plays a dominant part in the utilization of phytin phosphorus, according to recent findings by the Wisconsin station. The bone ash values of rats fed the phytin phosphorus along with adequate vitamin D were but slightly lower than those of rats receiving an inorganic phosphorus supplement. It is concluded that the low availability of the phytin phosphorus in cereals has been overemphasized

in the past and that satisfactory bone development is possible with diets supplying only a normal amount of phosphorus mainly in the form of phytin.

The Nebraska station has found that destruction of an enzyme, phytase, by heating alfalfa during dehydration for making alfalfa meal renders it less valuable from a nutritional phosphorus standpoint. In feeding chickens, however, adding a little meat scrap and fishmeal to a ration of purely vegetable origin offset this disadvantage. It was also established that a blend of corn gluten meal and soybean meal in chick rations resulted in better utilization of protein than where soybean meal alone was used as the source of vegetable protein.

The importance of supplying manganese to laying hens was emphasized as the result of recent studies by the Texas station which revealed that one-fourth pound of manganese sulfate per ton of mixed feed suffices to meet the requirements. Egg production, fertility, hatchability, and eggshell quality were all improved by including this mineral supplement in an all-mash ration composed of natural feedstuffs. Also, it was found to be much more important to have added manganese in the feed of hens starting the second year of production than in that of pullets just beginning to lay, which is particularly important in view of the general practice of poultrymen and hatcherymen to use older hens for production of hatching eggs. The results of this research lend support to the practice of commercial feed manufacturers who for the past 6 to 8 years have been adding a pound of manganese sulfate to each ton of mixed feed.

ARTIFICIAL LIGHTING FOR POULTRY

Recent experiments have further clarified conditions under which artificial lighting may be expected to increase the productivity of laying birds.

Late hatched pullets may be hastened to sexual maturity and intensive egg production by use of artificial lights in the early fall period according to North Dakota station findings. In an experiment of 48 weeks' duration, starting in mid-October, the favorable effects of lighting such late-hatched White Leghorn pullets occurred almost entirely within the first 15 weeks of the experimental period.

In experiments at the Washington station designed to determine the effect of artificial lights on egg production, the results as a whole indicated that the time at which artificial light is given is not important provided a total of 13 hours of incandescent light per day is supplied. Any decrease from 13 hours resulted in decreased egg production, and any increase above 13 hours did not result in enough increase in egg production to warrant recommendation. Provided the 13 hours was received, there was no significant difference on egg production in the effect of intensities of Mazda incandescent light varying from 1 to 31.3 foot-candles, or in the effect of Mazda, Mazda plus CX ultraviolet, ruby red, and red fluorescent light on egg production.

In three separate experiments at the Florida station, birds exposed to continuous lighting for the 24 hours laid an average of 2.44 percent more eggs than those receiving a gradually increasing schedule of lighting. The gradual increase in length of day as administered in these experiments produced a greater initial response in increased egg production, but later there was a greater refractoriness to light stimu-

lation than occurred in all-night lighting. The birds receiving all-night lighting consumed 0.32 pounds less feed per dozen eggs than birds receiving the increased schedule of lighting. The time of laying was during the daylight hours and was unaffected by the changing schedule of lighting used.

The extent to which turkeys may be stimulated to early egg production by artificial lighting is largely dependent on light intensity according to California station findings. A minimum light intensity of about 2 foot-candles produced a maximum response. Light intensities of 0.3 to 1.0 foot-candle produced a slower response; and dim lights of less than 0.1 foot-candle had no effect as compared with unlighted birds.

IMPROVING LIVESTOCK THROUGH BREEDING

Improved standards for the selections of superior breeding stock and the application of scientific breeding methods point the way to increased productive capacity and greater efficiency of production in the livestock of the Nation.

Particularly noteworthy is the recent adoption as a new breed of hogs of an experimental inbred line of swine developed by the Minnesota station from an original crossbred foundation of Tamworth and Danish Landrace parent stock. This new line which has been designated as Minnesota No. 1 is the result of over 7 years of intensive swine breeding by the Minnesota station as a part of the program of the Regional Swine Improvement Laboratory involving cooperation of the Department and several State experiment stations in the Corn Belt. The new breed has proved to be highly fertile, vigorous, and capable of fast and economical gains. It is proving particularly useful in crossbreeding for efficient pork production.

The nature and extent of hybrid vigor in single crosses between inbred lines of Poland China swine is indicated from an analysis of 28 intrasire comparisons included in 56 inbred litters from 11 lines and 60 single cross litters representing 43 different combinations by the Iowa station cooperating with the Department. Mortality before and after birth was lower in crosses than in inbreds. At 5 months of age crosses exceeded inbreds by 1.4 live pigs per litter. Although both groups were suckling inbred sows, the crosses were a little heavier than inbreds at birth and at 21 days, and at 56 days the crosses averaged 3.4 pounds heavier and by 25 pounds at 154 days of age. With the differences in litter size the total litter weights of crosses at this age exceeded inbreds by 290 pounds. Although the crosses grew more rapidly, both crosses and inbreds required as much feed per 100 pounds of gain from 84 days to 225 pounds. Crosses seemed to have a lower dressing percentage and less fat, but plumper hams, than inbreds.

Many of the characters of economic importance in beef cattle, including birth weight of calves, weaning weight, daily gain, final weight, efficiency of gains, slaughter grade, carcass grade, and area of eye muscle all have a high degree of heritability according to studies conducted cooperatively by the Montana station and the Department. These findings show the possibilities of fairly rapid improvement in beef cattle through rigid selection and use of superior breeding stock. Progeny performance tests to determine the transmitting ability of sires has a particularly prominent part in such a program.

The possibilities and limitations of inbreeding dairy cattle as a means of producing lines having a high degree of purity for desirable characteristics is indicated in Wisconsin station findings. While inbreeding generally tended to result in some lowering of milk production and body size, notably heart girth, the offspring of some sires could be inbred as much as 25 percent without apparent decrease in body size or production. While the development of good inbred lines in cattle is a time-consuming and at times disheartening process, efforts of the Wisconsin, New Jersey, and California stations continue to give evidence that such lines can be produced which have particular merit in line-cross and top-cross breeding for the production of superior dairy cattle.

An extensive analysis of the occurrence of female sterility in dairy cattle by the California station led to the conclusion that heredity plays a more important role in female sterility than is generally suspected. The evidence indicated that the female sterility transmitted by each of the bulls tested followed a single autosomal recessive factor with a sex-limited pattern of inheritance. Obviously, careful selection of breeding stock to eliminate this defect is of considerable importance.

Preliminary results of a breeding experiment at the Utah station where two groups of white-faced ewes were bred, one group to pure-bred Rambouillet rams and the other to Columbia rams, indicate that crossbreeding with Columbia rams results in a lamb with a more open face, less body folds, improved type and heavier average weight at weaning time than lambs produced by using Rambouillet rams. The adaptation and suitability of the Columbia crossbred sheep to the ranges of southern Utah need further study before definite recommendations can be made.

In a comparison of imported Wyoming and native West Virginia ewes all bred to Southdown rams at the West Virginia station, there was little difference in weight of lambs derived from both groups, but there was a great difference in weight of wool clipped from the ewes. In 1945 and 1946 the western ewes sheared at the rate of 9.4 and 10.03 pounds of wool each and the native ewes 5.14 and 5.79 each, respectively. As a result the net income from the western group of ewes was considerably higher than from the native stock.

Continued studies at the Maryland station indicate that shank length in heavy breeds of chickens is an effective, simple criterion for use in selection of efficient breeding stock. The long-shanked strains in both the New Hampshire and Barred Plymouth Rocks tended to grow faster and utilize feed better than the progeny from the short-shanked strains. At 10 weeks of age a high positive correlation between body weight and shank length was demonstrated for both Barred Plymouth Rocks and New Hampshires. Since strains differed significantly in body weight at 4 weeks of age, the most effective selection of birds for breeding purposes to effect differences in growth rates of progeny is thought to be on the basis of shank length and body weight at approximately this age.

In selected strains of red varieties of chickens, highly effective sex identification of baby chicks was possible on the basis of male chicks having a relatively large white spot in the web region of the dorsal wing region, according to Oklahoma station findings. It is suggested,

for those who wish to improve sex identification in these red-colored strains, that only those chicks having larger white areas on the dorsal surface of the wing web be saved. The general color tone does not need to be dark, but should be distinctly pigmented and uniform in both sexes. The head should be as deeply pigmented as the back. The advantages of such a simple process of sex identification are obvious.

That resistance to disease and the constitutional vigor of the domestic fowl can be influenced by selective breeding and progeny testing is a conclusion of the Virginia station. In eight generations of selective breeding for long life versus short life, strains have been developed in which the average span of the females was 43.9 days longer for the birds in the long-life strain based on a maximum length of life of 525 days.

Leukosis, a poultry disease, which includes several forms, such as fowl paralysis and tumors, causes an annual loss of about 4 or 5 million dollars to the poultry industry of New York State. Breeding experiments at the New York (Cornell) station have produced strains of poultry that are comparatively resistant to leukosis. The resistant strains are more able to withstand the serious infection that occurs during the first two weeks after the birds have been hatched.

The domestic fowl is most susceptible to pullorum disease when from 2 to 3 days old. Indiana station experiments show that plasma of day-old baby chicks showed bactericidal activity. Chicks from breeding stock of high bactericidal activity showed greater bactericidal action than chicks from stock of low bactericidal action, the difference in bactericidal action between the two lines of chicks approximating that found between the strains of adult fowls. These findings indicate that it might be possible to select breeding stock for resistance to pullorum disease on the basis of bactericidins of the plasma of the chicks when 1 day old.

ARTIFICIAL BREEDING AS A MEANS OF IMPROVING ANIMAL PRODUCTION

Recent developments in the techniques of artificial insemination have greatly increased the potentialities of this practice for extending the usefulness of superior sires and reducing the cost of breeding service.

Successful artificial insemination of dairy cows with semen diluted 100-1 has been made possible through recent results of the research of the New York (Cornell) station. During the past year and as a direct result of this research, 65,700 cows were bred to an average of 34 bulls. Thus each bull was bred, on the average, to 161 cows per month. With natural service, a bull ordinarily serves 20 cows per year. Accordingly, 3,250 bulls became replaceable through artificial insemination. It costs approximately \$150 per year to feed a bull. The saving in feed cost alone on the 3,250 replaceable bulls amounts to \$487,000 per year. Based upon actual records, the value of the increased milk produced as a result of artificial insemination during the year 1945-46 was \$725,000. The saving in feed cost and the value of the increased milk totals \$1,212,500. As the program expands, this figure will be much higher in succeeding years. The opportunity of spreading the good qualities of superior sires over the herds of the State will mean increased income to dairymen and more milk at a lower cost to consumers.

The New York (Cornell) station has further demonstrated that sulfanilamide controls bacterial growth in diluted semen, depresses glucose and oxygen utilization by spermatozoa, stimulates glycolytic processes by the spermatozoa, and increases their livability on storage. In two field trials sulfanilamide did not alter the fertility level in one test and gave an increase of 4 percent fertility in the other. The number of cows which can be bred with the single service of a bull has been doubled by these investigations.

In an attempt to find dyes which could be used for coloring stored semen samples without impairing the value of the semen for artificial insemination purposes, the Wisconsin station found that Nile blue sulfate, neutral red, and Sudan III, each in concentration to impart a distinct color to the sample, could be used satisfactorily. The value of this procedure as a basis for positive identification of semen used in artificial-breeding practice is very great, since a common weakness in field operation has been the inability to positively label source of semen with consequent loss of identity on frequent occasions.

The Wisconsin station also has further perfected a synthetic pabulum for the dilution and preservation of bull semen. Its essential ingredients should include freshly purified lipids, specific sugars—glucose and galactose—a buffer system, a gum to supply the proper physical consistency, and an agent to control bacterial contamination. The use of this new diluent promises to extend the useful life of stored semen.

THE USE OF HORMONES IN ANIMAL PRODUCTION

Research is pointing the way to use of hormone preparations, both naturally occurring and synthetic products in regulating various functions of the animal body and thereby increasing its usefulness for specific purposes.

The possibility of inducing estrus or heat period in sheep at a desired time of year in order to permit breeding for early or off-season lambs is indicated in New Jersey station experiments. When 177 anestrus ewes received either one or two injections of pregnant mare serum, which is a potent source of gonad-stimulating hormone, 136 came into estrus and mated, 22 following a single injection and 114 following a second injection usually made 16 days after the first. Of the 70 ewes which lambed, 5 had received one and 65 two injections.

Following investigations by a number of stations which demonstrated that synthetic thyroproteins, an iodinated casein product possessing thyroidal or thyroxine activity, will increase the metabolic rate and stimulate higher production of milk in cows, eggs in poultry, etc., the Missouri station has studied the effectiveness of various methods of administering the product to ruminants. It has found that the subcutaneous administration of a sample of thyroprotein was 20 times as effective as the same sample when fed. Similarly, *d*, *l*-thyroxine administered orally was only about one-eighth as effective as that administered subcutaneously. The administration of thyroprotein orally in dry form in a capsule was about twice as effective as when the same preparation was suspended in a slightly alkaline or in a phosphate buffer solution and given as a drench. Coating the thyroprotein particles by stearic acid, paraffin, beeswax, rosin, Clarite, Vinylite, and linseed oil in every case reduced the biological effect.

While oral administration in dry form is obviously the simplest method, tests will be continued to find ways of increasing its effectiveness.

Numerous investigations have been undertaken on the use of thiouracil and related compounds for reducing thyroid activity in animals, thereby reducing the metabolic rate, increasing rate of fattening, etc.

Inclusion of two-tenths of 1 percent of thiouracil in the ration of fattening hogs of the Missouri station resulted in average daily gains of 2.1 pounds as compared with gains of 1.4 pounds in untreated control animals. The test animals were less active, and at the end of the period they were shorter and fatter than the controls. Although they gained weight more rapidly and more economically, it is believed that their increased gain was not true growth, but apparently an example of retarded growth with rapid gains in weight due to deposition of an excessive amount of fat.

Indiana station experiments indicated that thiouracil at levels of 0.025, 0.05, 0.10, and 0.20 percent had a progressively increasing effect on the weight and microscopic anatomy of the thyroid gland of the chicken when it was fed between the sixth and fourteenth weeks of age. The average thyroid weight increase at the 0.20 percent level approximated 20 times normal. Growth was retarded but not significantly except in males when artificial light was used during the night. Market grade and fat deposition were improved by thiouracil, although the treated birds made less gain and efficiency of feed utilization was greater.

Perosis, as characterized by an enlargement of the tibiometatarsal joint and by a thickening and bending of the metatarsal, was obtained in young chicks by the feeding of relatively high levels of thiouracil (0.5 percent) over a period of 5 weeks at the Maryland station. The disorder was not prevented by the addition of manganese, choline, nicotinic acid, biotin, or riboflavin to the thiouracil-containing ration, but it is suggested that thyroxine may in some manner aid in the prevention of perosis under normal conditions. The growth-inhibiting effect of thiouracil in the ration of young chicks at 0.1 to 0.2 percent levels also was established.

The addition of a synthetic estrogenic compound, 3,4-dianesylhexane to the ration of broilers at the rate of 50 milligrams per pound of feed during the final 2 weeks of the fattening period resulted in marked improvement in the rate of fattening and the fat grade of the birds, in trials at the Oklahoma station. Administration of the drug resulted in a very marked increase in the concentration of free fatty acid and cholesterol in the blood of the chickens which undoubtedly is associated with the rapid rate of fat deposition resulting from its use. These striking results will stimulate further research on methods of using this or similar compounds to maximum advantage for all classes of poultry with the definite possibility of commercial application of the findings.

Consumption of diethylstilbestrol at 0.70 to 1.55 milligrams per pound of feed improved the market grade and the rate of gain of many of the experimental lots of young cockerels of different ages in Michigan station experiments. A definite antigonad effect was also observed. There appeared to be no advantage in continuing the feeding period beyond 6 weeks. The age of the birds when feeding was started had no noticeable effect on the influence of stilbestrol.

Old hens, $2\frac{1}{2}$ years of age, were hormonized for a 26-day period in New Jersey station trials, one group being fed dianesylhexane in the feed at the rates of 0.01 and 0.005 percent, another group Dienestrol in the feed (0.01 percent), and a third group had pellets of diethylstilbestrol implanted into the necks and shanks. The treatments did not influence the feed consumption, egg production, gain in body weight, or market quality of the carcasses. Similar treatments were effective in improving the grade of the carcass of males 18 to 20 months of age, but they did not increase the gains in weight significantly, nor improve the eating qualities of the meat appreciably.

MAINTAINING HEALTH OF FARM ANIMALS

Mastitis studies were a major field of inquiry, especially the value of penicillin treatments. This drug was found by the Michigan station to be effective for acute local and acute systemic mastitis caused by streptococci or staphylococci. Case histories of a considerable number of treated animals showed that 200,000 units of penicillin given intravenously and 100,000 units injected into the involved quarter or quarters and repeated at 12- or 24-hour intervals usually resulted in prompt clinical improvement, followed by clinical recovery in acute systemic mastitis. Two injections of 200,000 units of penicillin administered intravenously and 100,000 units injected into the involved quarter or quarters at 12-hour intervals, followed on successive days by 1, $\frac{2}{3}$, and $\frac{1}{3}$ grains of sulfanilamide per pound of body weight, effected clinical recovery almost as rapidly as where the penicillin treatments were repeated many times.

In Wisconsin, penicillin was found to be effective against ordinary streptococcic mastitis, the most common type of mastitis in that State, whether the cows were dry or in milk. Single large doses of penicillin cured about 50 percent of the quarters infected with chronic streptococcic mastitis, and three large doses (50,000 Oxford units per dose) given at 24-hour intervals cured 92 percent of quarters infected with the same type. These findings attest the value of penicillin, and the station has suggested a mastitis-control program based on these findings.

In treatments with penicillin for streptococcic mastitis tested by the New Hampshire station, three injections at 24-hour intervals gave the highest percentage of cures; 92 percent of the cows and 95 percent of the quarters were freed from infection. Dosages of 20,000 and 75,000 units per injection were both effective. Less effective control was obtained with single doses of 100,000 or 200,000 units. One injection of 200,000 units cured 86 percent of the cows and 84 percent of the treated quarters. It is reported that veterinarians in New Hampshire are beginning to use penicillin for mastitis in commercial practice.

Investigations by the Missouri station revealed penicillin to be 75 to 80 percent effective in clearing mastitis infection following the injection of 100,000 to 200,000 units in two to eight treatments of 25,000 units in saline solution per dose. No harmful effects following its use were noted.

According to the Wisconsin station, the stage of lactation had no apparent effect on the curative process of penicillin treatment. Quarters producing highly abnormal milk at the time of treatment were rarely freed of infection, but in almost every instance the macroscopic

appearance of the milk was greatly improved. After the milk returned to normal consistency, which occurred after one to six milkings, no unfavorable change was noted in the production of milk.

In view of the increasing use of penicillin infusions, their effect on the bovine mammary gland is an important consideration. At the Minnesota station, in experiments where the cows were milked at regular intervals after such infusions, no demonstrable decrease in the quantity of milk was observed. Changes were noted in the character of the milk, varying in general with the quantity of penicillin infused, but it returned to normal in 3 to 4 days. It was concluded that penicillin is relatively nontoxic and that large amounts may be infused without danger of disturbing reactions.

A survey by the Washington station of 94 herds containing 3,580 cows representative of the State's dairy industry disclosed that 34 percent were affected to some degree by garget (mastitis). In the eastern United States, the bacterium known as *Streptococcus agalactiae* predominates. Bacterial examination showed that the predominant germs in the Washington State cases belonged to the genus *Staphylococcus*, against which penicillin was relatively ineffective.

The North Dakota station reported a case of mastitis in a newly calved Guernsey heifer in which the only organism obtained was *Clostridium perfringens*. Following large doses of sulfanilamide and the sloughing away of one quarter of the udder, complete recovery was eventually secured.

Still another form of udder disturbance was reported by the Michigan station in which an unclean milking machine contributed heat-resistant bacteria to the milk both directly during the milking process and indirectly by having served to inoculate the cows' udders with these bacteria. In this case, the cows rid themselves of the heat-resistant bacteria in periods varying from 1 to 4 months after the milk equipment was properly cleaned and sanitized.

A unit segregation system of eradicating swine brucellosis was evolved by the California station in cooperation with the Department. This system is based on data showing that young pigs are usually not infected at weaning and on the efficiency of the test when applied to the herd. A positive unit consists of a group containing reactors and nonreactors of breeding age that have been exposed to infection. A negative unit consists of young pigs that have been segregated from the positive unit since weaning.

A new vaccine for protecting against *Brucella* infections was prepared by the Michigan station. It has been found that several of the *Brucella* species dissociate into distinctly different mucoid or wax-like phases. These mucoid phases when injected into guinea pigs, rabbits, or cattle give rise in their blood serum to growth-inhibiting antibodies in high titer and engender in guinea pigs a high degree of active immunity against infection with the species of *Brucella*.

The continued occurrence of abortion in Bang's disease-free dairy herds led to additional study by the Connecticut (Storrs) station of other possible causes, and to the finding that a protozoon, *Trichomonas fetus*, is an important cause of early abortion in certain herds. Methods of detecting infected bulls which spread infection in cattle have been difficult, as microscopic examinations are tedious and uncertain, and attempts to grow the trichomonads on special media often fail be-

cause they are destroyed by contaminating species of bacteria. The station solved the problem by adding antibiotic agents to the basic medium, thus suppressing the growth of bacteria and permitting the growth of *T. fetus*. Best results were obtained with 100 units each per milligram of streptomycin and penicillin.

Control of enterotoxemia (pulpy kidney disease) in lambs was achieved by the Oregon station by the use of an alum precipitated toxoid prepared from *Clostridium perfringens* type D. In extensive field trials, injections of this toxoid apparently reduced enterotoxemia losses and appeared to be a promising method of control.

Fowl typhoid was diagnosed by the Delaware station in a flock of guineas on a farm where it previously had been found involving the chickens and turkeys. It was not possible to definitely determine the primary source of infection, but it is suggested that poultrymen attempting to eradicate fowl typhoid or pullorum disease should consider the possibility of the guinea fowl acting as a carrier of one or both diseases.

Studies of the sulfa drugs and their application to animal diseases also were conducted at a number of stations. In 69 cases of acute calf pneumonia, only 3 out of 47 calves failed to respond to sulfapyridine, while 12 receiving sulfathiazole and 10 sulfadiazine all recovered. With calf scours, 51 of 57 cases responded to sulfaguanidine and 24 of 27 cases to sulfasuxidine. Both of these diseases are usually of high mortality. Thus, the Pennsylvania station reported that the sulfonamides and supportive treatments properly prescribed by a qualified veterinarian will in most cases control or alleviate cases of calf scours and pneumonia, although care in application is necessary because sulfonamides are especially toxic to young animals.

A comparison of the efficacy of five recently developed sulfonamides against fowl typhoid was made by the Delaware station using chicks of various ages artificially inoculated with *Salmonella gallinarum*. Sulfamerazine and two other sulfonamide compounds were found to be highly effective in reducing the mortality, while 50 percent sulfathalidine and sulfasuxidine were less promising.

In observations on the prophylactic and curative value of sulfaguanidine in swine coccidiosis at the Hawaii station, young pigs were heavily infected with oocysts from mixed cultures of *Eimeria deblickei* and *E. scabra*, and given the drug, mixed with feed, for several days. All the pigs which received prophylactic treatment remained normal and made satisfactory body gains, while untreated control pigs developed diarrhea, lost appetite, and made either little or no body gain. It was concluded that prophylactic use of sulfaguanidine inhibits the life cycle of swine coccidia and prevents symptoms associated with the disease, and that when given as a cure, the drug brings about a reduction in oocyst output, thus preventing the spread of the disease. It may also bring about a quicker termination of the diarrheal condition.

The effectiveness of sulfaguanidine in controlling losses and establishing immunity from cecal coccidiosis in artificially inoculated chicks was demonstrated at the Delaware station and in two commercial flocks of broilers. When chicks were treated for a continuous period of time beginning before or at the onset of a natural outbreak of cecal

coccidiosis, symptoms and losses were checked, but susceptible chicks remained and went through the disease after termination of treatment. A schedule of intermittent sulfaguanidine feeding coordinated with the development of the natural outbreak appeared to give the greatest protection from losses in birds passing through a natural infection with cecal coccidiosis.

The Washington station has proved that sulfaguanidine is also effective for turkey poult.

In the treatment of cecal coccidiosis in 6-week-old White Leghorn chicks by the Michigan station, the soluble sodium salt of sulfamerazine given in the drinking water was very effective in both the control and the treatment of *Eimeria tenella* infections, and all birds consuming enough of the drug to reach the level previously found necessary with sulfamethazine survived. No untoward results as manifested by weight changes were noted.

Sulfamerazine was found by the South Carolina station to be effective in reducing the mortality from a natural outbreak of pullorum disease in baby chicks in which treatment was not begun until 14 days after the onset of the disease. It is regarded as being effective in such outbreaks if an early diagnosis is established and treatment is provided promptly.

Beneficial results were also obtained by the California station when sulfamerazine alone, or in combination with sulfathalidine, was given in dry mash to turkeys in the early stages of a prevalent respiratory disease before the exudate in the air sacs became caseated. No advantage could be observed in using the combined drugs, and, as in the treatment of fowl coryza (*Hemophilus* type) with sulfathiazole, symptoms reappeared after treatment was discontinued.

Experiments conducted at the Maryland station indicated that sulfathiazole may have marked value in combating fowl cholera. In preliminary experiments, the sulfa drug provided a high degree of protection for experimentally infected chickens, while at the same time untreated fowls were succumbing to the disease at a high rate. A limited number of trials with sulfathiazole against natural outbreaks of the ailment on the farm have also yielded encouraging results.

On the other hand, in experiments by the California station, neither sulfathiazole nor sodium sulfathiazole proved to be effective as a flock treatment for the respiratory disease of turkeys noted above when given in doses readily accepted by the birds. The drugs were also ineffective against two outbreaks of acute fowl typhoid of turkeys. A deleterious effect on egg production was noted when adult turkeys were given in excess of 0.5 percent sulfathiazole in the mash. Both feed and water containing sodium sulfathiazole were unpalatable, especially for young turkeys. Mash pellets containing sulfathiazole appeared to be more distasteful than dry mash containing the same level of the drug.

The discovery and purification of streptomycin in highly active concentrated form by the New Jersey station, and the evidence presented by the station as to its antibiotic activity against bacteria causing a number of important diseases of man and animals, has prompted a great deal of research as to uses and methods of manufacture. Grants-in-aid of more than a half million dollars for

clinical study of this new drug have been made available to the National Research Council by the Streptomycin Producers Advisory Committee which represents 11 pharmaceutical manufacturers. Commercial production, which has increased in recent months, is expected to be further accelerated in a \$3,500,000 plant under construction. Already it has been used successfully in the treatment of urinary infections, tularemia, typhoid, and other diseases.

Pressure sprays of DDT to protect sheep against sheep ticks and wood ticks were being increasingly used by the Idaho sheepmen following a widely distributed publication of the Idaho station outlining practical methods of application whereby 400 or more sheep can be treated per hour in chutes not over 30 inches wide, using 4 pounds of 50 percent wettable DDT powder to 100 gallons of spray applied under high pressure. The method is used to protect sheep going to summer range, to eradicate ticks after sheep are brought back to winter quarters, and again just before lambing.

Data obtained from feeding trials at the Washington station indicated that the toxicity to swine of lead arsenate spray residues is much less than has generally been supposed. One pig consumed, in two feeding periods of 103 and 180 days, the spray residue on the peelings from 2,200 pounds of heavily sprayed apples which contained 114.8 grams of lead arsenate in the form of spray residue. This amount was greatly in excess of that which would be consumed by pigs receiving cull apples or pears fed according to commercial practices; nevertheless this pig gained in weight approximately as well as the control pig and no abnormalities were apparent in the blood studies. Similar results were recorded for three pigs fed lead arsenate, arsenic trioxide, and a smaller amount of spray residue.

Toxicity of sodium chloride to baby chicks was noted by the Kentucky station. Not only was water from a saline or soda-water well containing chlorine equivalent, to 0.54 percent sodium chloride and sodium equivalent to 0.7+ percent of sodium chloride toxic, but experimental use of a solution of pure salt in a concentration of 0.5 percent and 0.9 percent as drinking water produced a disease in day-old chicks identical with that resulting from use of the well water. Concentrations of 1.5 percent and 2.0 percent NaCl in the water caused acute toxicity with nervous disturbances, including somnolence, convulsions, incoordination, and inability to stand.

Excessive amounts of molybdenum were found by the California station in the forage and in the viscera of young cattle in a localized area of Kern County, Calif., and it is assumed that a disease observed in these animals resulted from the ingestion of excessive amounts of molybdenum in the forage. Some symptoms of the disease, as observed in the field, were reproduced by administering daily doses of sodium molybdate to a heifer calf.

Sulfur in combination with protein concentrates was found by the Colorado station to result in a heavy mortality when pellets of cottonseed cake, linseed meal, and sulfur were fed to fattening lambs and accidentally consumed by cattle. In paired experiments with sheep, no deaths followed the separate feeding of the protein concentrates and sulfur, but tests with graduated amounts of the mixture indicated that a dosage of 10 grams per kilogram of body weight approximated the minimum lethal dose for sheep.

High protein intake affords more protection against selenium poisoning in animals than a low protein diet, according to findings of the Wyoming station. Continued intake of selenium at subintoxication levels reduced food intake so that animals receiving high protein feed fared better than those on low protein feed. Sheep on a high protein diet were able to consume 20 milligrams of selenium daily for 25 days before exhibiting toxic symptoms, whereas, those on a low protein diet showed definite evidence of intoxication when fed 15 milligrams daily for 6 days. Thus it is evident that the protein content of the ration is of marked importance in seleniferous areas.

Crotalaria spectabilis was demonstrated by the Louisiana station, in experimental feeding of cattle and chickens and field studies with cattle, to produce toxicity of a chronic nature with fatal effects after the slow, cumulative assimilation of the toxic principle weeks or even months after grazing or feeding. The poisonous alkaloid, monocrotaline, was isolated from all portions of immature plants in flowering or early pod stages but was most highly concentrated in the seed portions of the plant. Notwithstanding the outstanding value of *C. spectabilis* as a leguminous cover crop and its low palatability, its restriction to areas not grazed by livestock is deemed necessary.

Results from the California station have shown that the leaves, seeds, and seed capsules of durango root (*Datisca glomerata*) are definitely toxic. Feeding of sublethal doses to sheep and cattle resulted in diarrhea, loss of appetite, and general depression. Because of its low palatability, it was difficult to induce the sheep to eat the plant. Despite the high toxicity of durango root, it is doubtful whether it has been the cause of any great number of cattle losses annually. However, it is undoubtedly one of the undiagnosed losses among cattle in the Sierra foothills.

Investigations by the Florida station of a peculiar and often fatal condition affecting both beef and dairy cattle in many areas of Florida indicated the cause to be plant poisoning associated with photosensitization resulting from eating the ornamental shrub *Lantana camara*, which in many sections has escaped from cultivation. In experimental feedings made with the plant, as small as $\frac{3}{4}$ to 1 pound of the mature, frosted, and dried leaves was sufficient to produce typical symptoms of chronic poisoning of 5 weeks' duration in animals weighing 400 pounds and confined in the sunlight. Cattle which have become familiar with the plant by long association do not usually eat it, but its removal from unfamiliar locations or fencing it off is advocated. Direct sunlight should be avoided with affected animals.

The presence of a toxic principle in a common spurge, *Phyllanthus abnormalis*, was demonstrated by feeding it to cattle, goats, and sheep in trials by the Texas station. A destructive action on the liver and kidneys was noted with a variation in toxicity in the plants from different areas. Drying the plant appeared to have a destructive effect on the toxic principle. Goats and sheep appeared to be more resistant than cattle. It is thought that serious cattle losses in one area of Texas characterized by hepatic cirrhosis but not associated with the grazing of *Senecio* probably are attributable to this spurge.

In an attempt to investigate the causative principle of cornstalk poisoning, the South Dakota station determined the effect of different

forms of nitrate and the accumulation and transfer of nitrogen-containing materials in the plant. These studies indicated that nitrate is reduced to ammonium or some similar compound before it can enter into metabolic reactions within the corn plant. Corn which was forced to absorb large amounts of ammonia accumulated asparagine, glutamine, and α -amino acid nitrogen, but "true protein" did not increase.

Internal parasites of sheep continued to be a major problem.

Studies were carried on by the Kentucky station to determine the longevity of parasitic larvae on permanent pasture when rested from grazing. The findings indicated that keeping sheep off a pasture for 3 to 3½ months during midsummer and early fall should reduce nematode larvae on the pasture sufficiently for practical control, especially when combined with correct use of phenothiazine.

The efficacy of phenothiazine was studied by the Missouri station. Liquid phenothiazine every 4 weeks from December to early April and then allowing access to phenothiazine-salt mixture (1 part phenothiazine to 10 parts salt) was found to be very satisfactory in controlling nodular worm infestation, and held the stomach worm, *Haemonchus contortus*, infestation down to an average of about 19 per lamb. However, this method did not satisfactorily control *Ostertagia*, *Nematodirus*, *Cooperia*, or tapeworms, and whipworm counts were not materially different. Average weight of the lambs was very much higher. Phenothiazine was not found toxic to sheep either in a 1 : 10 phenothiazine-salt mixture or when the medicine was given as a drench every 28 days throughout the entire year, and its use did not interfere with breeding efficiency. On the other hand, the Texas station reported experiences which indicated that phenothiazine may be toxic to ewes during the later stages of pregnancy, with a risk of abortion during the period of approximately 2 to 3 weeks prior to parturition.

Observations by the South Dakota station in cooperation with the Department and others indicated that tapeworms are an important cause of scouring in lambs. Treatment with lead arsenate removed safely and effectively a high percentage of *Moniezia expansa* and proved remarkably effective against scouring.

The Mississippi station also found that the lead arsenate treatment checked diarrhea and controlled *M. expansa*, although in some cases retreatment was necessary.

IMPROVING QUALITY OF DAIRY PRODUCTS

New and improved processing methods which will facilitate the distribution and increase the use of milk and its products are essential to a continued high level of milk production in this country.

Studies at the Michigan station indicate that homogenized milk can be partially condensed so as to reduce it to one-third to one-half of its volume and held for a comparatively long period (several times the normal holding period for ordinary raw milk) and then be reconstituted by the addition of water without apparent changes in taste, appearance, or other qualities. This procedure promises to be well adapted to commercial use and effects a very substantial reduction in distribution costs for fluid milk.

Frozen fluid milk can be held about 50 percent longer in frozen storage before serious destabilization of the protein occurs than frozen

concentrated milk (milk prepared as for canning) the Pennsylvania station has discovered. On the other hand, the frozen concentrated product will resist the onset of oxidized flavor for almost 50 percent longer than will frozen fluid milk. These products were used on hospital ships and in hospitals during the war years and to some extent up to the present. Either process might be utilized in holding surpluses of milk for use at a later date or as a means of storage during shipment to areas that are short in milk supply.

The cause of the development of tallowy flavor in fresh milk—long a problem of great importance to the dairy industry—has been traced by the New York (Cornell) station to the reaction involving the rate of loss of ascorbic acid (vitamin C) in the milk. Market milk contains two forms of vitamin C—ascorbic acid and dehydroascorbic acid. The reaction that causes the breakdown of fats in the milk, and thus results in the development of the tallowy flavor, can be inhibited by quick and complete oxidation of ascorbic acid to dehydroascorbic acid, and by the subsequent heat treatment in pasteurization. Using this procedure, fresh milk has been kept in good condition at ordinary refrigeration temperatures for as long as 2 weeks without loss of palatability. This research promises to be very useful in the milk powder industry. It will also apply in other fields, such as citrus juice preservation, and that of certain meat products.

High forewarming temperature of about 180° F. for skim milk before condensing is beneficial in prolonging the keeping qualities of dried ice cream mixes and the retardation of oxidized flavor development according to Illinois station findings.

The Washington station has proved that the amount of benefit derived from the use of dried milk in baking depends upon the percentage of whey protein present. Having established this fact, the station then developed a quick and reliable method to estimate the weight of whey protein in milk and milk products which will be useful in several directions, including prediction of baking quality and checking on heat treatment given to milk.

The temperature to which skim milk must be preheated to secure optimum baking quality was found by the Minnesota station to be a function of the time of heating. Heating for 30 minutes at 75° C., gave the best results by the vat method, whereas improved results by the flash method were obtained as the temperature was increased to 86°. The heat-treatment studies on skim milk are of value as a guide to the optimum treatment required in the commercial production of nonfat milk solids for the baking industry.

INCREASING YIELD OF FARM FISH PONDS

Late winter and early spring fertilization of ponds was found by the Alabama station to stimulate the spawning of bream and thereby greatly increase the catch. It was found possible to produce two crops of goldfish minnows per year in a pond and up to 76,000 goldfish were produced per acre per crop. To raise goldfish successfully all other fish must be excluded from the pond. Fathead minnows were produced in ponds at rates of 31,000 per acre. They also spawned in the presence of bream and catfish. Addition of organic materials supplying CO₂ to the water increased fish production in ponds fertilized with inorganic fertilizers. A combination of largemouth

buffalo (plus a few carp) and bass gave a total production of 846 pounds of fish per acre in a fertilized pond, while a carp and bass combination made a total production of 320 pounds.

FIELD CROPS, PASTURES AND RANGES, AND WEED CONTROL

CORN

Nearly four-fifths of the record United States corn crop of 1946, estimated at 3,712,000,000 bushels, was the offspring of hybrid seed, which was planted on 2 of every 3 of the 91,487,000 acres of corn in the United States. This expansion can be attributed in large measure to research of the State experiment stations and the Department. It represents an increase of hybrid corn from 143,000 acres in 1933, 0.1 percent of the total United States corn acreage, to 62,680,000 acres, or 67.5 percent of the 1946 crop, according to surveys by the Department. Of the 1946 crop, about 54,500,000 acres, or seven-tenths of the hybrid corn, were grown in the North Central States. Hybrids were planted on half or more of this acreage in 28 States.

The stations within the several regions of the country, cooperating with the Department and other agencies in State and regional corn-improvement programs, have continued to bring forward promising combinations and to exchange parent stocks for production of additional superior adapted hybrids of good quality. Performance trials of experimental and commercial hybrids and varieties, conducted by the stations in practically every corn-growing section of the States, are establishing for farmers the production values of the new corns.

Although hybrid corn production is most extensive in the Corn Belt where the enterprise first became a commercial success, adapted crosses are being developed locally throughout the country, providing suitable hybrids in the northern and northeastern areas where silage is a major use of corn, in the South, and in irrigated areas of the West. A Tennessee station hybrid developed from the productive Neal Paymaster variety, for example, considerably outyields corn commonly grown in Tennessee, and other hybrids from this source have surpassed all other hybrids and varieties in recent Georgia station tests, and similarly are recommended by the North Carolina station. Corn improvement work by the Tennessee station cooperating with the Department has resulted in average yield increases of about 4 bushels per acre on the 2,500,000 acres of corn in the State, annual benefits from the research approximating 8 million dollars.

Corn hybrids developed by the Louisiana station and the Department produce 20 to 50 percent more grain, have more erect plants at harvest, and the ears are more resistant to earworm and weevil damage than open-pollinated varieties. Increase in corn yields in 1946 due to the foundation inbred lines supplied by this activity would exceed 1 million bushels. These hybrids also have made noteworthy performance in adjacent States. The Texas station's program of hybrid corn breeding is also beginning to pay good dividends. A new white hybrid has given outstanding results in higher yields, larger ears, and resistance to lodging, and is now in extensive commercial use. Very promising yellow hybrids are now being released. More than 800,000 acres were planted to Texas hybrid corns in 1946, which, by conservative estimates, resulted in additional yields of over 4 million bushels.

As a direct result of corn breeding by the Colorado station, approximately 85 percent of the irrigated corn acreage and 30 percent of the dry-land corn acreage in the State are planted to hybrid corn. During the past 4 years, irrigated corn has increased over 4,000,000 bushels, largely because of the use of hybrid seed. The planting of 32 percent of the corn area in North Dakota to hybrids in 1945 is attributed to improvement and development of hybrid corns by the North Dakota station. Increase in yield from use of hybrid corn in North Dakota amounted to over 200,000 bushels annually. Hybrids, all yellow dents, produced by the Oregon station, have definite adaptations. Oregon Hybrid 100 is adapted as a grain type to sections of western Oregon and most of the Willamette Valley needing early maturing corn. Later maturing hybrids for both grain and silage and having limited or general adaptations include Oregon Hybrids 355, 525, 570, and 695, which are practically identical with Wisconsin hybrids of the same numbers.

Sweet-dent hybrid silage corn, a development in the sweet corn breeding program of the Connecticut (State) station, has large stalks and ears, matures earlier, and starts faster in spring than U. S. 13, the corn most widely grown for silage in the area, and farmers claim that its silage is preferred by cows to regular field corn silage. The sweet-dent ears when cooked were much sweeter, tenderer, and better flavored than U. S. 13, although below the Long Island Beauty sweet corn in quality.

Maine B, the flint-dent hybrid corn introduced by the Maine station, has aided dairymen and poultrymen greatly in relieving the feed shortage, averaging 72 bushels of mature air-dry corn per acre.

In commercial hybrid seed corn production, there are special hazards associated with detasseling of female parent plants, particularly loss of upper leaves, accelerated smut infection, and inadequate pollen supply. Experiments of the Nebraska station and experiences of others indicate, however, that as a general principle detasseling does not affect grain yields materially unless it is accompanied by loss of leaves or followed by severe smut infection.

Maximum corn yields cannot be obtained through the use of hybrids alone, according to the Pennsylvania station. Adequate use of fertilizer, lime, and legumes, as well as stands of plants adjusted to the fertility level of the soil, proper cultivation, and other good practices should go hand in hand with the use of hybrids. Proper spacing for best yields on the particular soil fertility level is a production essential. The Georgia station found that poor stands were often responsible for low yields; yields rose both in farmers' fields and in station experiments with increasing numbers of plants per acre. Current recommendations are to plant 21 inches apart in $3\frac{1}{2}$ -foot rows, or 18 inches in 4-foot rows, which provides more than 7,000 plants per acre. This station also finds that adequate fertilization and proper cultivation are essential. The Mississippi station reports that high rates of nitrogen per acre allow the number of plants per acre to be increased greatly over farmers' ordinary spacing. With 40 to 60 pounds of nitrogen, most soils in Mississippi should carry at least 8,000 plants per acre and up to 12,000 plants in the richer soil areas, including the Delta.

WHEAT

Varieties of wheat that produce well in spite of disease and insects, drought, and winterkilling are noteworthy products of the coordinated hard red winter wheat improvement program in operation in the Great Plains region of the United States since 1930, cooperative between State stations and the Department. An inclusive plan of operation has been developed for production and rapid testing of new wheats, and the new varieties are distributed and recommended for areas of adaptation which may cover parts of several States. Much has been learned regarding the influence of agronomic characters, disease resistance, and physiological behavior on yield. Milling and baking characteristics have received much attention, both in varietal evaluation and research on phases of wheat quality. Results from research studies are used in planning future work in the improvement of winter wheat. The Cache, Comanche, Marmin, Nebred, Pawnee, Tenmarq, Wasatch, Westar, Wichita, and Yogo, hard red winter varieties, and Austin, a soft wheat, have been released. Estimates are that these varieties currently occupy more than 12,500,000 acres. Conspicuous examples are Comanche wheat, developed by the Kansas station, and Pawnee wheat by the Kansas and Nebraska stations, both superior varieties produced under this cooperative program. Their greater resistance to diseases and insect pests and other improved qualities enable them to outyield older varieties which are being replaced rapidly. Pawnee wheat, according to estimates, was grown on 1,000,000 acres in Kansas, Nebraska, and Oklahoma in 1946, and Comanche wheat was grown on 1,500,000 acres in Kansas, Oklahoma, and Texas.

Cadet, a new beardless wheat, selected by the North Dakota station and the Department and distributed for increase in 1946, compares favorably with all other varieties of hard red spring wheat in resistance to steam and leaf rust and is similar to Thatcher and Newthatch in resistance to stinking smut. It grows taller than most beardless wheats, does not shatter readily, requires a few days longer to ripen, has strong straw, and has given good results in milling and baking tests. Its lateness may make Cadet most useful in the more northern and northwestern sections of North Dakota, where ripening temperatures usually are not so high, and thus later varieties can more often realize their fullest yield.

Austin wheat, a new soft red winter variety, derived by the Texas station and the Department, is characterized by high resistance to leaf and stem rusts and to loose smut. It resembles Mediterranean in most agronomic and in milling and baking characters. Austin may be used satisfactorily in the trade channels for making flour for home consumption. It is recommended for central Texas from Fort Worth and Dallas southward. First distributed to growers in central Texas in 1942, the variety has become so popular that about 1,000,000 acres were grown in 1946.

Rescue, a sawfly-resistant wheat developed at the Swift Current (Saskatchewan) station and named in 1944, was made available to the Montana station. The 2 bushels of seed received were planted by the Arizona station for growing in winter months, and the Arizona-grown seed was sent back to Montana for spring planting. The system en-

abling production of two seed crops in a year yielded 4,747 bushels, which were distributed to selected growers for planting in 1946, and by 1948 enough seed would be available for all wanting to grow the variety. This timesaving international and interstate cooperation means an ultimate saving to farmers of several million dollars, as evidenced by the fact that wheat-stem sawfly destroyed 5,000,000 bushels of wheat in 1945 in parts of northern and northeastern Montana.

Vahart wheat, a head selection from Redhart by the Virginia station, has proved to be one of the most resistant wheats to loose smut, although about as susceptible to leaf rust as other common varieties. It matures about 1 week later than Redhart, is slightly taller, and stands up as well or better. Vahart is as winter hardy as V. P. I. 131, Leap, or Forward, all of which it outyielded.

Newcaster wheat, a selection from and similar in quality to Fulcaster, was distributed by the Illinois station to foundation seed growers in 1945. Newcaster is superior to Fulcaster in being resistant to loose smut and having stiffer straw.

Fairfield, the soft winter wheat released by the Indiana station in 1943, continued to expand acreage in central and northern Indiana. Its high yielding ability and resistance to winterkilling and desirable milling and baking qualities enable it to replace the Purkof variety.

About 58 percent of the 1945 Georgia wheat crop was of the Sanford variety developed by the Georgia station and the Department and released in 1940, with indicated increased value of over \$400,000 to Georgia farmers from the use of this new variety as compared with the usual varieties. Marfed, a spring wheat resistant to smut and mildew and a better yielder than Federation, developed by the Washington station and the Department, was being increased for general distribution in 1947. Orfed, the new winter wheat developed in the same cooperation and released to growers in 1943, proved resistant to most races of smut and of good yield and milling quality, with high test weight and stiff straw, and was grown on more than 250,000 acres in the winter of 1945-46.

Effects of production practices on quality were also important considerations in the wheat improvement programs. Hard flinty varieties, as Chiefkan, the Kansas station and the Department determined, were consistently high in maltose value of flour, an important quality factor to the baker, whereas the soft wheat Clarkan gave much lower values. Tenmarq, Turkey, and Standard Blackhull were about equal. Kawvale, officially graded as a soft wheat, was in the Tenmarq-Turkey group. Maltose value seemed to be an inherited character, although its annual expression was largely modified by environment. That the thiamine content of dry-farm wheat is considerably higher than that of irrigated wheat was determined by the Utah station. The study also showed that flour may be kept for 6 to 12 months without appreciable loss of thiamine. With excessive dosages or exposure periods, fumigants commonly used to treat wheat in storage may cause loss of viability, particularly if the grain moisture exceeds 12.5 percent. With ordinary dosages and exposures, the Kansas station and the Department noted, these fumigants affect temporarily the baking quality of flour made from the wheat, but the effects disappear if the grain is aerated enough. Loss of viability from many causes may impair baking quality, yet the studies indi-

cated that partial or complete loss of viability due to fumigation does not necessarily impair baking quality even after storage of the wheat for 1 year.

OATS

The dependable new oats varieties resulting from coordinated oats-breeding programs of the State stations and the Department equal or surpass the older ones in yield and test weight, resistance to rusts and smut, and have stiff straw that facilitates combining. Their merits are such that oats are now replacing barley in many localities and wheat as a small grain crop in some places. The new Tama, Boone, Control, and Marion oats, four rust- and smut-resistant varieties developed as a part of the program at the Iowa station, produced 32.1 percent more than the better old varieties in 1943 on 66 percent of the Iowa oats acreage, resulting in an increased income approximating \$23,000,000. In 1944 the new varieties were grown on 90 percent of the oats acreage and produced 38.7 percent more per acre, with a resulting income increase of about \$25,000,000. By 1945, they were grown on 98 percent of the acreage with an increase of 32 percent in acre yield. The increased value of the 1945 crop resulting from their use is estimated at \$34,000,000.

Osage and Neosho oats, released by the Kansas station and the Department in 1945, are resistant to the races of rusts and smut common in Kansas. Together with Boone, Tama, and Cedar oats, these varieties gave a return in 1945 estimated at \$1,700,000 over former standard oats varieties grown in Kansas.

The value of the new varieties has extended far beyond the States of origin. For example, Clinton, Vicland, Boone, Tama, and Marion were outstanding in State-wide tests of the Illinois station, and Osage and Neosho excelled in Kentucky station experiments. The South Dakota station reported that 75 percent of the total oats acreage in the State (3,440,000 acres) was seeded to the newer varieties. Even though these varieties, developed elsewhere, were not deemed particularly adapted to South Dakota conditions, they outyielded the old standard varieties 10 to 25 bushels per acre, the total increase being valued at about \$16,770,000. Cedar and Tama have led in tests by the Nebraska station in eastern Nebraska, Marion is popular in the northeastern part of the State, and Clinton also has done well. The new varieties with increased acre yields of high-test weight have been made available to growers and feeders in Indiana by the Indiana station. A conservative estimate of an increase of 7 million bushels (value at least \$5,000,000) was obtained in the 1945 oats crop; these oats were of such excellent quality that livestock feeders were using them increasingly to replace wheat and corn during the critical feed shortage.

A number of the new oats varieties, including Clinton, Benton, Mindo, and Eaton (all Bond hybrid varieties) and Marion, according to the Iowa station and the Department, are also resistant to the hitherto unrecognized oats disease variously known as foot rot, helminthosporium, or H 96, which has caused Nation-wide losses. Indications are that all oats varieties that received their resistance to crown rust from Victoria, including Boone, Cedar, Control, Forvic, Osage, Overland, Tama, Ventura, Vicland, and Vikota, all spring-sown oats, are susceptible to this helminthosporium blight. If the latter vari-

eties must be planted, treatment of the seed with an organic mercurial disinfectant is advised.

A few years ago the Tennex, Fulwin, and Forkeddeer, three varieties of winter hardy oats, were developed by the Tennessee station. Before their development, the State was growing about 100,000 acres each year. The new oats gave such satisfactory results that today there are 359,000 acres of oats grown in the State, with an average yield of at least 10 bushels more per acre than the old varieties. At the present price of oats this means an additional income of \$3,000,000 annually to the farmers of the State. These oats have also been widely used in adjoining States. Fulwin and Forkeddeer are indicated by the Georgia station for mountainous sections where danger of winter-killing exists.

Eaton oats, another development in the cooperative programs, selected further at the Michigan station, has a stiff straw, white kernels, and a medium test weight, is relatively high yielding, and is resistant to stem and crown rust and to smut. About 1,000 bushels of registered seed were produced in Michigan for distribution in 1946.

Forvic oats, a new variety developed at the Wisconsin station, yielded 10 percent higher than Vicland in 1945 tests. In 1946, 2,500 acres of Forvic are being grown to provide certified seed for 1947 distribution. Vicland, released earlier and related to Forvic, was outstanding in New Jersey station tests. Overland, a new oats developed cooperatively by the Washington, Utah, Idaho, Colorado, and Wyoming stations and the Department, was being multiplied in 1946 for general release to growers. It is notable for high resistance to all smut races tested and has resistance to crown and stem rusts in the Northwest, although not to the new helminthosporium disease. It has short exceedingly stiff, straw and high test weight and is especially suitable to arid locations, either on dry or irrigated land. Another new oat highly resistant to all forms of rusts and smuts in the area, but earlier than Clinton and Benton, was being multiplied by the Indiana station for further test in central and south-central Indiana. It is high in test weight and in percentage of meat and gives a good acre yield.

BARLEY

Bay, a new barley variety selected by the Michigan station and released in 1945, has stiff straw, erect 6-rowed heads, and smooth awns, makes good yields, and is as acceptable for malting purposes as Wisconsin Barbless (Wisconsin 38) and possibly superior in certain respects. Cascade, a superior 6-row, rough-awned, facultative winter barley, derived by the Oregon station from a composite cross made by the Department, was released to farmers in Oregon.

About 25 years ago a hooded barley, Tennessee Beardless 6, developed by the Tennessee station, provided farmers with a winter grain crop that they had not been growing before. Previously, practically no barley was grown in the State. This hooded barley was later supplemented by a rough-awned barley, Tennessee Winter 52, with much higher yielding qualities, and during the past few years a smooth-awn type, known as Jackson No. 1, has been developed which yields better than the other strains. At present there are more than 100,000 acres of barley grown in Tennessee which average about 24 bushels per acre. The annual benefits derived from this work are at least \$1,000,000.

RICE

Delrex, a new variety of rice recently developed by the Louisiana station and the Department, is of special interest to those who enjoy rice with a nutty, popcorn-like flavor and fragrance.

The Louisiana station found that deep applications of nitrogen in a complete (8-8-8) fertilizer have been more efficient in increasing the yield of rice than nitrogen applications in the flood water or at seed level. Net losses of nitrogen have occurred where large applications were made in the surface water. Deep application has increased the yield of rice about 11 bushels per acre.

POTATOES

New potato varieties brought out in the National potato breeding program cooperative among most of the experiment stations and the Department provided about one-fourth of the record supply, 42,057,335 bushels, of certified (33,005,803) and War-approved seed stock (9,051,532) available for the 1946 spring planting. Katahdin, the first of the new varieties developed and released about 13 years ago, supplied 4,875,651 bushels, and several of the varieties introduced later supplied the following: Chippewa 1,721,074, Pontiac 1,472,223, Sebago 1,201,169, and Red Warba 538,815 bushels. Considerable amounts of quality seed were also provided by other new varieties, as Houma, Sequoia, Kasota, Menominee, and Warba. A number of new varieties released during the year are variously characterized by superior yield, coloring, and market quality, regional adaptation, and resistance to or immunity from diseases and insects.

New potato varieties released to commercial growers by the New York (Cornell) station include Ontario and Seneca, late-maturing and white-skinned, and Cayuga, medium late and deep russet, all scab resistant. Placid with 344 bushels per acre and Virgil with 297 bushels led in tests of new blight-resistant varieties. Beech (125-6) and Lake (116-3), new seedlings outstanding in scab resistance by the Iowa station, were released to Iowa farmers, and seed stock would be available in the fall of 1946. Wisconsin Russet Sebago, a selection developed by the Wisconsin station in cooperation with the Department, possesses more scab resistance than the regular smooth Sebago and is becoming increasingly popular with the Wisconsin growers. Teton, a new potato resistant to bacterial ring rot, developed by the Wyoming station and the Department and released in 1946, showed superior qualities and wide adaptation in various parts of the United States. It made high yields, was disease resistant, and had acceptable cooking quality in tests of the New York (Cornell) station.

On Lordstown silt loam, the New York (Cornell) station made 52 bushels more U. S. No. 1 Green Mountains from 2,400 pounds of 5-10-10 fertilizer than with 1,200-pound applications. Highest yields came from broadcasting one-half of the fertilizer and then plowing in one-half in equal bands at planting. The mixture of one-half potassium chloride and one-half sulfate of potash-magnesia outyielded other of potassium sources. Potatoes grown at the New Hampshire station in soil treated with lignin or lignin plus sulfur, and harvested when 98 days old, gave increases of 50 and 33 percent, respectively, over controls, made larger tubers with lower moisture content and fewer culls, and had higher percentages of starch—19.68

percent for lignin alone, 11.77 for lignin-sulfur, and 10.24 percent for controls. The lignin-treated plants grew faster and also showed deeper green color and much more abundant foliage.

Potatoes grown from large whole tubers and cut seed pieces showed the greatest net financial return per acre in experiments by the Maine station and the Department. The largest whole tubers used were slightly under 2 inches in diameter, while the largest cut pieces weighed 2 ounces. Consistent increases in yield were obtained during each of the years 1943-45 with increasing size of whole and cut seed used. Total yields rose and the average size of the tubers produced decreased as the seed spacing was narrowed. Effects of size of seed on yields were greater with the Green Mountain and Sebago varieties than with Katahdins. Increases in yield resulting from the use of larger seed sufficed to more than pay for the extra cost of the seed and for the extra harvesting costs associated with the higher yields. Seed growers can profitably sell for seed purposes most of the tubers smaller than $1\frac{7}{8}$ inches in diameter and could use large seed as well as close spacing, about 6 inches, to advantage, but a table stock grower should use a spacing of not less than 9 inches.

Losses from sprouting and shriveling of potatoes in storage were greatly lessened by use of a hormone in Missouri station tests. The 1 gram of naphthaleneacetic acid required per bushel of tubers was applied in impregnated shredded paper distributed in the potatoes. Mixing it with brown dust also proved effective, as did spraying it in a finely atomized form when the potatoes were passing over the grader. A storage temperature of 50° F. for potatoes appeared superior to others tested by the Maine station, if vitamin C retention be considered a criterion of quality. Varieties differed in response to temperature and duration of storage during 7 months. In both years, Mohawk remained at a relatively high vitamin C level and Chippewa at a low one throughout the period. Sebago decreased at a rapid rate, whereas Green Mountain tended to improve its position. Varietal differences in vitamin C diminished greatly under influence of storage, but were not nullified completely.

SWEETPOTATOES

The sweetpotato, one of the most important field-grown food crops in the South, continues to be a major factor in the postwar economy of the region. The stations and the Department have extended their efforts in breeding improved varieties for food, feed, and manufacture, and in developing more efficient production practices.

The breeding program of the Louisiana station has resulted in the development of improved varieties of sweetpotatoes and high-quality seed stock that enabled the State to produce over 10 million pounds of dehydrated sweetpotatoes for the Army and allied agencies in 1945, and to supply certified seed for local use and for carlot shipments to other States. The carlot movement of sweetpotatoes, begun since 1940, totaled 8,000 cars in 1945. Five new feed dehydration plants were built, and this number was expected to be more than doubled in 1946. Canning of sweetpotatoes has been carried on in 10 factories, and more plants are in prospect. The new varieties bred by the station and contributing to these large-scale developments include Pelican Processor, a high starch producer analyzing 26 to 36

percent starch, and a number of high carotene seedlings for table use and dehydration. Three of the latter have twice the carotene content of the standard Porto Rico variety. This station, the Mississippi, South Carolina, Texas, and other stations have also developed from their experiments practical methods of handling and storing seed stock, plant bed management, and plant production, cultural and fertilizer practices, and harvesting, curing, and storing methods.

BEANS

A productive new strain of Pinto bean, selected by the Idaho station from a cross between Pinto and Red Mexican beans and released in 1946, is resistant to mosaic and curly top diseases. An increase of 15 percent in yield over standard varieties is expected in extensive plantings of this new strain in southern Idaho.

Montana No. 1, a mosaic-resistant strain of Great Northern bean, released by the Montana station in 1943, was the only variety now in commercial production that was fully mature in 1945 at the first frost September 9. Rapid progress by this strain is evidenced by the fact that in 1945 128 acres were devoted to raising seed for certification which would plant about 4,000 acres in 1946.

COTTON

New and better varieties of cotton which could furnish fiber of the types and qualities essential in manufacturing yarns, fabrics, and other articles for both war and peacetime uses and cottonseed for oil, food, and feedstuffs were the main objectives of the programs of cotton improvement of the experiment stations and the Department.

Arkot 1, a new cotton variety from Rowden parentage released by the Arkansas station, has proved to be a superior yielder, particularly on less fertile soils, is highly resistant to fusarium wilt and its lint has very desirable spinning characteristics. Arkot 2, derived from Stoneville 2-B, combines a high degree of wilt resistance with the good yield and high quality of the parent stock. These new cottons are meeting a definite need for better adapted varieties for the Upland and Delta cotton areas, respectively, of Arkansas. One promising extra staple hybrid of the Louisiana station, Tidewater \times 45-210, made 429 pounds of $1\frac{5}{16}$ -inch staple per acre. A selection from a back-cross hybrid of Miller and Deltapine 11, ranking high at Baton Rouge, produces well, and has 39.6 percent lint, a boll size of 60 per pound of seed cotton, and locks tending to be stiff, which make it an excellent picking cotton.

Acala 1517 WR, the verticillium wilt resistant selection from Acala made by the New Mexico station and the Department, has given exceptional performance in the irrigated Southwest, has yielded well, and in spinning tests has exhibited desirable quality factors characterizing Acala 1517. A supply of 8 to 10 tons of foundation seed made available to the New Mexico Crop Improvement Association was being increased in 1946 so that an abundance of seed would be available in 1947. Cotton following sorghums in rotation had a lower percentage of verticillium wilt than cotton after cotton.

Fruiting and shedding of cotton in relation to light and other limiting factors were studied by the Texas station. Differences in sensitivity of cotton varieties to unfavorable light conditions indicated

the importance of careful selection of varieties for a given region, according to prevailing weather conditions during the fruiting season, and demonstrated to breeders the need for attention to these inherent varietal differences. Varieties as Stoneville 2B, Coker 4-in-1, Deltapine 14, Half-and-Half, Roldo Rowden, and Washington were found in general to be less sensitive to unfavorable variations in light conditions than Qualla, A. D. Mebane Estate, Rogers Acala, and Lone Star.

Duration of safe storage of cottonseed was found by the Department and Tennessee station to depend upon climatic conditions at the storage location and ranged from 1 to 2 years in the lower Coastal Plains to 5 to 6 years along the northern rim of the Cotton Belt. Fuzzy seed was slightly lower in moisture content than acid-delinted seed and averaged slightly higher in germination. Seed treated with a fungicidal dust was higher in germination than untreated seed, probably because of control of mucor and other fungi during germination.

Cotton was defoliated by the Oklahoma station and the Department with applications of 30 to 35 pounds per acre of a material containing calcium cyanamid when the plants were moist. Resulting loss of leaves in from 5 to 15 days permitted earlier harvest with consequent saving of more of the crop, higher grade of lint and seed, and better control of insects. The Mississippi station observed no harmful effects on lint and seed quality when calcium cyanamid dust was applied when bolls were 30 days or older. It found that defoliation improved the grade of machine-harvested cotton and enabled faster hand-picking.

HEMP

Hemp (*Cannabis sativa*) made greatest response in yield to nitrogen in experiments of the Iowa station and the Department, highest increases coming with 100 pounds of nitrogen per acre. In tests by the Illinois, Indiana, and Wisconsin stations in similar cooperation, major response was also made to nitrogen. On the poorer soils nitrogen increased yields without detrimental effects on fiber quality, while on good fertile soils yield response was small and reductions occurred in fiber strength. Adjustment of rates and balances of nutrients to insure maximum production and maintain fiber quality is an objective in hemp fertilization.

Commercial hemp was grown in north-central Iowa in 1943 and 1944 in response to wartime demands for the fiber. The Iowa station found the chances good for a successful crop in the area, whereas chances of retting hemp successfully were much poorer due to great divergences from normal in total rainfall and pattern of distribution. Hemp should be harvested early in September with as short a stubble as possible and should be ready for turning by the middle or latter part of the month. Turning is not essential if retting proceeds uniformly throughout the swath. Controlled methods of retting in general released a fiber superior in quality and uniformity to that ordinarily obtained by field retting. Retting in tanks under anaerobic conditions was faster, especially at 37° F., than any of the aerobic methods.

SOYBEANS

Soybeans have attained a permanent place in the agricultural economy of the United States. Although the phenomenal expansion in

acreage and utilization stimulated by wartime needs and greatly aided by research of the stations might normally have covered from 10 to 25 years, the industry asserts that it was largely a sound expansion, the result of actual demand. Demand for soybeans and their products, in fact, has continued unabated into the present post-war period because of scarcity of fats and oils and the critical protein supply. Further research on new or unsolved problems of soybean production continued to bring forward better varieties and improved cultural, harvesting, and storage practices.

New varieties provided by cooperating experiment stations and the Department have become increasingly popular. Sharp shifts to the higher yielding varieties, as Lincoln (originated at the Illinois station) occurred in the acreage planted in major soybean-growing States. In 1944 only small acreages of Lincoln were grown; in 1945 about 10 percent of the soybean acreage in Indiana and Illinois, with lesser amounts in other States; while in 1946 one-half of the total acreage of soybeans in these two States were in Lincoln, with sharp increase in other major North Central States. The Ohio station estimated that the increased values of soybeans produced on Ohio farms—the greater amounts of oil and meal derived from growing Lincoln and Earlyana (developed by the Indiana station), which it recommends—would total from 3 to 4 million dollars. Richland, Gibson, Patoka, and Earlyana, all varieties developed by the Indiana station, and, more recently, Lincoln have made almost inestimable money returns for Indiana farmers, enabling the maximum production of soybeans of high oil content. The farm income of Tennessee farmers, estimates the Tennessee station, was increased about \$1,214,000 in 1945 through the use of Ogden and Volstate soybeans, superior varieties developed by the station. These widely adapted varieties were being grown with profit from Missouri to the Carolinas and farther south.

Roanoke, a new medium-late soybean, developed by the North Carolina station and the Department, has a high oil content and is adapted to State conditions, particularly the Piedmont and Coastal Plains areas. It might well replace Woods Yellow, currently the predominant variety in the State, which it surpasses in yield, resistance to shattering, and oil content.

A cross strain surpassing Richland in yield and oil content, equaling it in lodging resistance, taller, and as well adapted to central Indiana, was being multiplied for release by the Indiana station. Several new soybean strains of Patoka-Gibson maturity, suited to southern Indiana, showed higher yield and oil content than Gibson, Patoka, and Chief, and equaled Patoka in lodging resistance. Viking, a new soybean variety from the same cross as Chief, was increased for further distribution by the Illinois station. The Pelican, Acadian, and LZ varieties recently released by the Louisiana station and the Department have made a very creditable showing during 3 years in cooperative tests in Southern States, yield well, are nonshattering, and their seed is high in oil as well as protein. Pelican and Acadian are also remarkable for high forage yields.

TOBACCO

Tobaccos resistant to diseases, bred by the Kentucky station, have been highly profitable to growers in Kentucky and other tobacco sec-

tions as well. Commonly grown tobacco varieties were highly susceptible to usual diseases affecting the crops, but selection and hybridization since 1920 have resulted in the successive introduction by the station of the burley varieties Ky.5, a root-rot resistant, in 1930; Ky.16 in 1936, and later Ky.19 and Ky.41A. Each had leaf or plant characters and disease resistance superior to those released earlier. About 90 acres of certified seed of Ky.16 and Ky.41A are grown annually by about 35 seed producers. Ky.22, a variety of still higher resistance and better quality, introduced recently, was grown on about 10,000 acres in 1946. The increase in value of the burley crop by about 25 to 30 million dollars a year over potential production of old varieties, the result of this enterprise, was attributed to higher yield, disease resistance, and a product of greater uniformity and high quality. Ky.120 and Ky.134 are dark fire-cured tobaccos resistant to black root rot. Ky.52 burley, Ky.150 dark fire-cured, and Ky.160 one-sucker, all mosaic resistants, have been readily accepted by growers and the trade because of great improvement in quality resulting from freedom from mosaic.

Yellow Special, a high yielding flue-cured variety moderately resistant to root rot, has led other varieties in tests over 7 years at Chatham, Va. This variety, released several years ago by the Virginia station and now widely grown, averaged 1,141 pounds, worth \$362 per acre compared to 1,062 pounds and \$332 for Yellow Mammoth—its nearest competitor. Two root-rot resistant lines, Nos. 7 and 9, have yielded slightly less than Yellow Special, although the value per pound of cured leaf has been similar. Mosaic-resistant lines of burley and flue-cured, also selected for root-rot resistance by the station, have good appearance and are expected to prove acceptable for commercial use.

Connecticut 15, a new variety of shade tobacco which shows marked resistance to black root rot, developed by the Connecticut (State) station, also surpasses ordinary shade strains in many other respects. It is very uniform in all characteristics, producing 20 to 25 marketable leaves as compared to 15 to 18 for ordinary shade tobacco, and the variety tops out later and is not so inclined to branch into long suckers at the top. The leaves are rounder and more desirable in shape than the common types which become pointed near the top of the plant. Connecticut 15 showed an increase of 34 percent in values per pound over other shade strains in the last 2 years. Tobacco men growing this variety report increases in acre yield of marketable leaves ranging from 25 to 50 percent. One grower of Connecticut 15 in 1945 produced \$7,000 worth of tobacco per acre. Connecticut 17 and G 4, other shade varieties developed by the station, also proved definitely superior in acre yields and grading to strains commonly grown in the Connecticut Valley.

A range of 80 to 90 percent relative humidity produced the best quality of leaf in curing experiments of the Maryland station and the Department. Humidity above 90 percent resulted in houseburn or decay of leaves. Temperature in itself appeared to have little effect on the quality of curing leaf. A tight-walled tobacco barn is needed to keep the humidity at 80 percent on dry days. On the other hand, burning charcoal in pits or pots lowers the humidity to the desired

level on damp days. Only a few of the days in any curing season are apt to be dangerously high in humidity. Daily checks on the moisture in the air, plus a few days of firing, may mean the difference between top-price and worthless leaf.

Tobacco, like other crops, needs boron for satisfactory growth and good quality. The Virginia station, working with Yellow Special and Mammoth Yellow flue-cured on Granville sandy loam, found that $2\frac{1}{2}$ pounds of borax per acre as a fertilizer supplement materially increased the acre yields and quality of the crop. Treated land averaged 1,247 pounds of tobacco, selling at \$577, and that receiving no borax made 1,186 pounds and \$550.

Suitable quantities of borax applied to Connecticut Valley tobacco land by the Connecticut (State) station have increased crop values by as much as 12 percent. The grading of Havana Seed tobacco usually was improved, although yields—averaging more than 1 ton per acre—were not affected by borax application. Fifteen pounds of borax broadcasted (together with regular fertilizer) furnished about 1 p. p. m. of boron, produced optimum response, and could be applied safely when boron need was apparent. Continuous use of not more than 5 pounds of borax per ton of fertilizer would be a safe procedure.

ALFALFA

Alfalfa has maintained a dominant position as a legume forage crop over the past decade, with an average annual production of about 30 million tons of hay a year. It usually ranks along with and often passes the popular clover-timothy mixture in total hay production. Continued high-level production of alfalfa is due in large measure to the hardy, productive, disease-resistant varieties adapted to diverse conditions, developed and released by the State experiment stations and the Department.

Ladak and the new Ranger are recommended for Minnesota because in Minnesota station tests they have proved much superior to the old standard Grimm wherever bacterial wilt depletes yields and stands. Ladak, all strains of Turkistan, and new strains or varieties developed for resistance, proved superior to other alfalfas in prolonged comparisons by the Washington station. Turkistan (19300), outstanding variety, combines high yielding ability with winter hardiness and wilt resistance. Ladak, less resistant to wilt than Turkistan strains, surpassed Northern Common strains in winter hardiness, wilt resistance, longevity of stand, and yield.

A superior alfalfa selected by the Virginia station from Kansas Common and adapted to southern agriculture, especially the Coastal Plains, recovers faster than the parent after cutting and can compete better with weeds. It outyielded Kansas Common by 76 percent at Williamsburg (with far less weeds and grass) and to a lesser extent at Blacksburg and Glade Spring, Va. Seed of the new variety is being increased before distribution to farmers.

That strains and hybrids differ inherently in carotene content was determined by the Nebraska station and the Department. New growth of field-grown alfalfa was higher in carotene than more mature growth, and strains showing least yellowing after leafhopper attack exceeded those which yellowed badly. In general, strains or

hybrids having a high leaf percentage contained more carotene than those with a lower leaf percentage. On the average, 77 percent of the carotene in the plant was found in the leaves.

Production and harvest practices, as well as varieties, developed in their investigations also have been made available during the year by the Virginia, Kansas, Missouri, and other stations.

Phosphorus fertilizer alone or in combination caused substantial yield increases in Washington station experiments with irrigated alfalfa, except on newly reclaimed land or where much manure had been applied. No combination with one or more of nitrogen, potash, calcium, or sulfur was materially better than phosphorus alone. Where available phosphorus was a limiting factor, treble superphosphate at the annual rate of 75 pounds per acre produced very good results, and as much as 150 pounds economically produced much larger yields. Manure, 10 tons per acre annually, was as effective as heavy phosphorus applications in maintaining alfalfa yields. Phosphorus or manure applications materially increased the percentage of phosphorus in the alfalfa plant material, thereby improving the quality of the hay for feed. The New Mexico station also found phosphorous of value to alfalfa under irrigation, recommending phosphates at the rate of 60 pounds of available phosphorous per acre each year for practically all soils that have produced any considerable amount of alfalfa.

OTHER LEGUMES

Sericea lespedeza, a perennial legume used for hay, grazing, and soil improvement, is increasing in importance, as is indicated by the total area of 40,000 acres reported growing in Georgia in 1945. The Georgia station finds that this legume has remarkable ability to resist drought and grow on poor land, although, like other crops, it does best on fertile soils. *Sericea* hay is leafy and cures easily. Hay yields at the station during 8 years have averaged 2.4 tons per acre. The crop has responded with increased yields to phosphate and lime on eroded and poor soils, and its removal of about 50 pounds of potash per acre in the hay crop of an average season suggests an annual top dressing of about 100 pounds of potassium chloride.

Sericea, rabbitfoot clover, and bicolor lespedeza, which averaged 5 percent tannin (a factor responsible for low palatability), are not so readily eaten as alfalfa, hop and white clovers, and sweetclover, which averaged only 1.3 percent at the Georgia station. Younger plants of *sericea* were found to contain less tannin than older plants, and when cut new growth contained less than old growth. Individual plants varied widely in tannin content, suggesting possibilities of developing a low tannin strain. Complete fertilizer and lime lowered the tannin content to 4.5 percent from 6.8 on untreated soil.

That protein content of *sericea* leaves can be used as a rough method of estimating tannin content—tannin being low when protein is high—was determined by the Department and the North Carolina station. Since a feed, both high in protein and low in tannin, is desirable, *sericea* should be used in as young a stage as is commensurate with longevity and high yield.

Sericea ordinarily leaves an appreciable nitrogen residue even when subject to annual crop removal, according to the Tennessee station. Medium to poor land in high-yielding *sericea* for years or longer could be expected to produce large yields of corn for several successive

years, with due attention to the possible potash and phosphorus needs of the soil.

Rotations which improve fertility may be started without loss in immediate income, the Oklahoma station reports, if sweetclover or lespedeza are sown in a nurse crop of small grain. Sweetclover seedlings survived between drill rows 14 or 16 inches apart but failed on adjacent areas during many seasons when the small grain rows were 7 or 8 inches apart. Grain yields were not seriously reduced at the wider spacing between the drill rows, and much better stands of sweetclover and higher yields of lespedeza resulted in many seasons.

Birdsfoot trefoil (*Lotus corniculatus*), according to the New York (Cornell) station, has distinct possibilities for hay and pasture on secondary or poorer soils where alfalfa does not succeed, where red clover is too short-lived for the rotation used, and summer conditions too droughty for persistence of white clover. The crop evidently cannot be expected to compete with alfalfa or red clover for hay production on the better soils and under a short-rotation system of farming. For pasture use, birdsfoot trefoil gave best results when seeded with an open sod-producing grass, especially with Kentucky bluegrass, timothy, or orchard grass. It compared favorably with wild white clover and maintained fall greenness for several weeks after the other legumes were severely injured and defoliated by frost. Birdsfoot trefoil was about as palatable as other legumes of similar nature and stage of maturity, and insofar as nitrogen, calcium, phosphorus, and lignin are concerned it was equivalent in nutritive value to alfalfa for hay and white clover for pasture. Experiments conducted by the West Virginia station and the Department show birdsfoot trefoil to be promising for restoring vegetation on badly eroded areas, particularly on eroded shale soils where excessive grazing and drought have caused damage.

Tropical kudzu (*Pueraria phaseoloides*), reports the Puerto Rico (Federal) station and the Department from their cooperative studies, is relatively resistant to drought, grows well in full sun and beneath trees of moderate shade, has no serious insects or diseases, makes good pasture for dairy cows in Puerto Rico, and produces abundant seed from which it is easily established. The legume tends to spread from an original planting when seeding is permitted, yet it may be destroyed easily by plowing. It covers the ground thoroughly and quickly from seed, thus helping to control hillside and gully erosion and at the same time adding organic matter and nitrogen to the soil.

Kudzu (*Pueraria thunbergiana*) required phosphates for establishment of satisfactory stands on depleted soils in experiments of the Alabama station and the Department. From 400 to 800 pounds of superphosphate was needed for maximum yield. Lime and potash applied together or as a supplement to 400 pounds of superphosphate also increased yields. Phosphorus and lime applied to kudzu resulted in higher phosphorus and calcium content of the hay.

GRASSES

New and improved forage crops that provide increase in farm income from hay, pasture, and seed have been bred, tested, and established by the stations cooperating with the Department. The Oregon station, for example, estimates the annual income from sale of seed of varieties developed in such cooperation at \$12,000,000. The large

acreages now producing these improved forage strains were formerly used for growing wheat and other cereal crops less profitable and less useful. These endeavors have made available to farmers much practical information on growing forages, recent examples being Alta fescue, Sudan grass, millets, sorghums, meadow foxtail, and Ladino and subterranean clovers.

Green stipagrass, an improved variety of feather bunchgrass (*Stipa viridula*), released by the North Dakota station and the Department, surpasses ordinary feather bunchgrass in vigor, size, and forage yields, and seed yields are satisfactory. This variety, one of the highest yielding of the cool-season grasses tested at Mandan, grows rapidly after defoliation and is especially useful for pasture seedings. It grows well with other grasses and should be seeded in mixtures for general farm use. It thrives on most soil types and probably can be grown successfully over most of the northern Great Plains. Mandan wild-rye, selected from Canada wild-rye (*Elymus canadensis*) by these cooperators, and an improvement over the parent type, is characterized by ease of establishment, rapid growth, long life, high yields of seed, and of finer forage, value in mixture with other grasses, wide adaptation especially on sandy soils, endurance of grazing, and superior resistance to rust.

Several new grasses have been brought forward by the Idaho and Washington stations and the Department. Bromar, a new strain of mountain brome grass, is highly resistant to head smut. It is very vigorous, has a longer season, and produces larger yields of forage and seed than mountain brome now in use. Primar, an earlier, more vigorous type of slender wheatgrass, has high resistance to stripe, stem, and leaf rusts, and mixes well with sweetclover in pastures.

Grasses found in experiments by the Alaska station since 1902 to be variously adapted to different conditions in the Territory included smooth brome grass; Russian wild-rye; tall oatgrass; meadow foxtail; slender and western wheatgrass; meadow, sheep, Chewings and creeping red fescues; Kentucky and Canada bluegrasses; and timothy. Methods have been developed for establishing and handling these grasses to replace or supplement the forage provided by the widely disseminated native grasses.

The seeding of crested wheatgrass on some 1 million acres of abandoned cropland in the State, the Montana station estimates, has added about \$2,000,000 to the income of livestock operators. This winter-hardy, drought-resistant forage grass was made available to Montana livestock growers more than two decades ago through the cooperation of the station and the Department. As dry-land pasture, it has produced an average of 78½ pounds of beef per acre per grazing season, or about 42 pounds more beef per acre than the amount produced on good native pasture.

Brome grass rapidly becomes sod-bound, with the result that in 3 to 5 years after planting yields of both seed and forage may become very low. Fertilization with nitrogen during the fall or early spring was found by the Kansas station to correct this condition, permitting normal production of both seed and forage. Application of 100 pounds per acre of nitrogen (as ammonium nitrate) resulted in yields of 450 to 600 pounds of seed per acre compared to 25 to 110 pounds from sod-bound fields. Forage yields, and to a similar extent pasture yields,

were increased after treatment approximately fivefold on extremely sod-bound areas and correspondingly smaller on less depleted sod.

PASTURES AND RANGES

Appropriate combinations of grasses and legumes are essential to productive, lasting pastures. Mixture of birdsfoot trefoil and bluegrass, outstanding at the Indiana station, made an acre gain of 264 pounds of beef, compared with 248 pounds from alfalfa-timothy. Birdsfoot trefoil outyields other pasture plants because of its ability to produce considerable gain on steers during the latter part of the season. It remains green and succulent during July and August.

Pastures, like other agricultural lands, must be fertilized for highest production. Plant foods are constantly removed from fields used for pastures in the form of meat, milk, and other products, and these losses are not entirely offset by the return of manure, plant residues, or nitrogen fixed by legumes. Pastures on Monongahela silt loam, seeded to Kentucky bluegrass, redtop, and white clover, and treated with lime and superphosphate or lime, superphosphate, and potassium chloride by the West Virginia station, gave profitable yield increases. There were more clover and bluegrass in all limed and fertilized pastures, and the herbage gained in contents of minerals and protein.

Nitrogen fertilization, especially with sodium nitrate, stimulated production of Bermuda grass pastures at the Georgia station, increased the protein content of the grass, and was definitely profitable. Greater returns per dollar invested in fertilizers were, however, obtained with phosphorus and limestone because they greatly stimulated production of winter-spring clovers. The main benefit from fertilization of pastures by the Alabama station was that it enabled the introduction of a spring clover into the grass sod, increasing the amount of grazing and furnishing herbage of a higher nutritive content. Most soils required lime phosphorus and potash for successful introduction and growth of spring clovers.

A heavy-utilization alternate system of pasturing either brome-grass-alfalfa or Kentucky bluegrass mixture, where enough land is available, is recommended by the Illinois station from its pasture studies with sheep. Both average seasonal production and annual gain per acre were greatest under this treatment. Greater gains were made by lambs and ewes at the Indiana station on Ladino clover-grass mixture than by those on alfalfa-grass mixture. The greater gains on the clover were made at a lower consumption of dry matter, explainable by the higher feeding value of the Ladino clover-grass mixture. The protein content of both Ladino clover and the associated grass averaged between 4 and 5 percent higher than alfalfa and its associated grass. Continuous grazing also resulted in better gains than rotation grazing on both mixtures.

That carrying capacity of a large proportion of Minnesota's 6 million acres of open permanent pasture could be increased from 35 to 100 percent or even better by following improved practices developed by the Minnesota station was shown by yields on pastures in southeastern Minnesota, variously treated by spreading of droppings, application of manure, use of commercial fertilizers, and renovation by disking, harrowing and reseeding, and prevention of overgrazing. Soil moisture tests made by the Wyoming station on pastures in three sections

over several years indicated that forage production of the next grazing season is associated to a large extent with the amount of moisture present in the soil in the previous fall. Determination of soil moisture in the fall may thus provide a basis for forecasting the probable carrying capacity of a given area in the next season, a definite aid to livestock producers.

Renovating unproductive hillside pastures, the Pennsylvania station and the Department found that the tillage implement best to use depends upon the topography and stoniness of the land and its susceptibility to erosion. Although the plow is most effective for killing existing vegetation, a primary requisite for satisfactory renovation, the disk and the field cultivator have the definite advantage of leaving a sod mulch on the surface, which provides an excellent seedbed and insures against soil erosion and water losses. Tillage operations are usually advisable during summer when hot dry periods may help kill the old sod. Lime needed is applied before the first disking, and mineral fertilizers may be worked into the soil during a subsequent disking, usually the last one. Seed sown on frozen ground in early spring and without a companion crop has resulted in excellent stands. One or two cuttings of hay or two grazing periods usually are available in the year of seeding.

Poor hill-land pastures were also revegetated for improved conservation and production by the West Virginia station and the Department. Satisfactory stands were obtained both by plowing and by shallow tillage, using a disk, spring-tooth harrow, or field cultivator for seedbed preparation. Shallow tillage usually resulted in more legumes, higher yields, and less bare space subject to erosion than areas either plowed or surface treated with lime and fertilizer. Best results were obtained with shallow tillage where surface vegetation was rather sparse and the ground moist or even wet, and in late winter or early spring. Although controlled grazing is desirable, good results were obtained even when the new seedings were heavily grazed. Manuring helped to prevent overgrazing and was always beneficial. White clover, alsike clover, sweetclover, orchard grass, ryegrass, and Kentucky bluegrass appeared to be the most promising plants in the mixture.

Short grass range, typical of the Great Plains, showed a general stimulation of the vegetation after closely spaced (less than 4 to 5 feet) treatments with the eccentric one-way disk, groover, or 8-inch moldboard plow, in experiments by the Wyoming station and the Department. Thinning the cover made available more moisture and plant food to remaining plants, and these plants usually equaled or surpassed production on nontreated range. Increase in western wheatgrass and other desirable species, resulting at the expense of blue grama, raised the total forage production, increased feed available in the early spring period, improved ability of the range to hold moisture, and improved the quality of range feed through the greater volume of a variety of grass species. The pits and grooves also served to retain excess precipitation. Range pitted with the eccentric disk or grooved at 2-foot intervals averaged 11 percent greater grazing capacity over 4 years, and 6 pounds more lamb gain per acre than nontreated range, and also had greater volume of perennial grass at the end of the grazing season. In the fourth year, treated range carried 36 percent more sheep per acre.

WEEDS

Remarkable advances in the control of weeds of field and truck crops, meadows and pastures, lawns and uncropped areas have been made by the experiment stations, often working with the Department. Recent accomplishments of particular interest are the development and use of selective herbicides, flame cultivation, controlled grazing, and specially devised cultural and crop rotation practices.

Use of selective herbicides has found broader application with the introduction of new organic chemicals, especially the growth-regulating and the dinitro compounds and the selective oils. The growth-regulating chemical 2,4-D (2,4-dichlorophenoxyacetic acid), extensively publicized as an herbicide, has been studied in numerous experiments in practically every State. Appraisal of results of tests to date indicate that 2,4-D is definitely good for the control of dandelions and other weeds on lawns, is probably good to use for certain weeds on pastures, is still questionable to control weeds in corn and small grains, and is at least promising, possibly in combination with tillage and cropping, on a considerable number of the bad perennial weeds.

A high percentage of alligatorweed (*Alternanthera philoxeroides*), a serious pest in certain sugarcane, rice, and truck crop areas in southern Louisiana, was killed with 2,4-D in Louisiana station experiments. Many other weeds, including nutgrass, cocklebur, ragweeds, rosebriar, water-hyacinth, and the rice weeds indigo, redweed, mule-ear, and several sedges, were also killed or at least weakened by 2,4-D. Tropical weeds killed at the Puerto Rico (Federal) station with a commercial mixture of 2,4-D included nutgrass (*Cyperus rotundus*), day-flower (*Commelina longicaulis*), caladium (*Caladium* sp.), water-hyacinth (*Eichhornia crassipes*), royal waterlily (*Victoria regia*), and lotus lilies (*Nymphaea* spp.).

Ragweed was killed at the Michigan station by a single application of 2,4-D at a concentration of 1,000 p. p. m. Pollen production by old plants was stopped, without killing the plants at once, by spraying with a concentration of 500 p. p. m. Faster response was obtained by adding very small amounts of sodium chlorate or ammonium sulfate. Pollen formation may be prevented by spraying ragweed just before flower-stalk elongation with 250 p. p. m. of 2,4-D. Development of pollen in both common and giant species of ragweed also has been prevented by the New York State station by spraying with 2,4-D early in August. Water sprays, for example, containing 0.1 percent of 2,4-D and 0.5 percent of Carbowax, at rates of 100 to 200 gallons per acre, or an oil solution of 2,4-D used in a fog applicator should be applied before pollen-bearing parts of the flower have opened and have begun to ripen. The spray should be used with caution near crop plants. Public health authorities, park commissions, and community groups are making widespread use of these results for the benefit of hay-fever sufferers.

Dandelion and buckhorn plantain were eliminated from lawns at the New Jersey station by spring, midsummer, and fall applications of 0.14 percent of 2,4-D. Stronger concentrations were needed to destroy certain other weeds. The 2,4-D killed weeds more slowly in cool weather than during hotter periods. A spreader or wetting agent applied with the 2,4-D increased the ease with which more

resistant waxy-leaved plants, as red sorrel or clover, could be destroyed. Kentucky bluegrass was found more resistant than Chewings fescue or Colonial bentgrass, although all of these grasses, cut at lawn mower heights, withstood applications of 2,4-D as concentrated as 0.56 percent. After treatment to eliminate weeds, the area should be fertilized and reseeded.

The New York (Cornell) station also finds the combination of 2, 4-D spray and fertilization desirable for lawn areas in New York. Fertilizer is applied in fall and spring at the rate of 20 pounds 5-10-5 to 1,000 square feet, the grass is cut to at least 1 inch high, and clippings are left on the lawn. The 2, 4-D is applied in May or June to remove dandelion or plantain and to kill young weed seedlings, and halt germination of any remaining weed or grass seed. Lawns once weed-free are fertilized again to thicken the turf and to crowd out weed seedlings. Dandelion could be eradicated almost completely by 2, 4-D spray at the Wyoming station without harm to bluegrass, although white clover might be injured. Best results were obtained where conditions favored rapid growth of grass, i. e., when daily temperatures averaged about 60° F.

The merits and limitations of 2, 4-D are being thoroughly appraised by the stations. California station research has shown that 2, 4-D leaves a deleterious soil residue and that the length of toxicity depends on soil temperature, moisture, soil properties, and dosage. The 2, 4-D may be leached from the soil, the rate depending on soil type. Both weed and crop plant species vary widely in susceptibility to injury, but if dosages are high enough all weeds can be killed. From experiments in 38 counties, the Colorado station grouped as promising as to reaction to treatment with 2, 4-D—bindweed, silverleaf, and woolly-leaved povertyweeds, perennial sowthistle, burdock, curled dock, fanweed, wild lettuce, lawn weeds, willows, cottonwood sprouts, and cattails. The responses of Canadian thistle, whiteweed, Russian knapweed, and leafy spurge were doubtful; and tame and weedy grasses, mouse-ear povertyweed, and a number of other weeds were resistant. For best results, the station indicated a concentration of 0.1 percent of 2, 4-D at the rate of 240 gallons per acre, with 100-pound spraying pressure, preferably in the prebloom stage, at 70° F. or higher. High soil moisture and high fertility, productive of rapid, succulent growth, were associated with good results.

The Idaho station and the Department, experimenting with 2, 4-D in 13 Idaho counties, recorded a top kill of dandelion of 99 percent with no recovery, and perennial sowthistle 99 percent kill and 3 percent recovery. While bindweed showed a top kill of 95 percent, 32 percent recovered. Canada thistle had lower rates of kill and higher rates of recovery. Only 34 percent of white top was top-killed, and it made a 75 percent recovery. Evidently much is to be learned about effectiveness of retreatment as well as other phases, for regrowth of bindweed seemed at about the same rate after the second and third applications as after the first.

Indiscriminate use of 2, 4-D sprays for control of weeds on ditch banks in cotton fields may result in destruction of considerable cotton adjacent to the irrigation ditches, according to New Mexico station findings. Extensive injury to cotton was a result of spray drift of certain highly volatile forms of 2, 4-D, but not due to presence of the chemical in the irrigation water.

Much of the research with oil sprays is in the advanced experimental stage, and a number of developments are employed widely by vegetable growers. The California station determined that in oil the olefinic and aromatic compounds are the ones which are toxic to plants. Flax is tolerant to the toxic materials in kerosene which kill wild oats and wild barley, suggesting the possible use of kerosene as a selective herbicide in flax. Kerosene and dry-cleaning fluid from naphthenic crude and kerosene from paraffinic crude plus 20 to 30 percent aromatic solvent were used satisfactorily by the New York (Cornell) station as sprays to kill noxious weeds in plantings of carrots, parsnips, and parsley, without injuring the vegetables, and at much lower cost than for the usual weed-control methods. Results have been so satisfactory that many carrot growers in New York State are using oil sprays for weeding carrots.

Stanisol, Sovasol, oleum spirits, and related oils were found by the Michigan station to give a 95-percent kill of annual weeds and grasses in carrots. Carrot plants were not usually injured at any stage of growth by these oils. Although oil sprays will not eradicate all the weeds in a carrot or parsnip planting, these materials can be used on many farms to greatly reduce the amount of hand labor needed for production of these crops. Oil spraying should be done when carrots are in the 2 to 3 "fern" stage of growth, and a second application may be applied at any time in the following 4 to 6 weeks. Bunching carrots probably should not receive more than one oil spray, and at least 4 weeks' time should elapse between spray application and harvest. From 75 to 100 gallons per acre of sprayed area gives satisfactory control.

During 1945 about 500 acres of carrots and parsnips in Massachusetts were sprayed with dry-cleaning fluids to kill weeds following findings of the Massachusetts station that oils of this type are satisfactory herbicides for these crops. Oils used in the experiments are of the petroleum naphtha type with an aromatic content of about 15 percent, commonly sold under various trade names for thinning paints and dry-cleaning clothes. The station finds that greater care must be exercised in using weed sprays than when applying insecticides and fungicides. Almost any type of spray rig may be adapted to application of selective herbicides, but special nozzles that deliver flat fan-sprays are necessary for best results. Particular attention should be given to the calibration of the tractor speed with the amount of spray delivered per unit of time.

Carbon disulfide, when injected into the soil, forms a toxic gas which permeates the pore spaces and renders the soil atmosphere poisonous to plant roots. The California station reports that different weed species have responded differently to carbon disulfide primarily because of their soil requirements and root distributions. The standard treatment devised is injection of 2 fluid ounces of liquid in holes 18 inches apart each way to a depth of 6 to 8 inches. Effectiveness of carbon disulfide, the station finds, is determined by many factors, mostly related to the soil. Rapid diffusion of the gas is favored by high soil temperature, low moisture content, and loose, open structures. Practical methods have been developed for using carbon disulfide under different soil conditions.

Nutgrass, according to the Alabama station, was eradicated by hens of the more active breeds, such as White Leghorns, from small ($\frac{1}{60}$

acre) pens, but hens were ineffective in larger ($\frac{1}{2}$ -acre) pens. They had to be numerous enough to keep the nutgrass leaves eaten to the ground, and grazing was continued through two successive growing seasons. Geese practically eliminated nutgrass from $\frac{1}{2}$ -acre plats cropped during two successive growing seasons to cotton not cultivated after chopping and siding. These geese required a grain supplement after nutgrass became scarce. Sale of geese and cotton largely defrayed the expense involved in the goose-cotton method.

Using a flame cultivator when corn was several inches taller than the weeds, the New York (Cornell) station killed practically all weeds in corn without injuring the crop, whereas even small weeds could hardly be killed without serious damage to spinach. Results with green beans, soybeans, peas, and cabbage ranged between those obtained with corn and spinach. The findings tended to support the view that after the first weed crop has been killed by flaming, there will be no more weeds during the season.

A flame weeder controlled weeds in cotton at the Mississippi station at a cost of 47 cents per acre compared to \$6 for chopping. A 2-row flamer covered nearly 20 acres a day at a cost of \$9, while a chopper could handle only three-fourths acre. Propane, kerosene, and butane were all found satisfactory for fuel. A simple burner designed by the Louisiana station has given better weed kill than any burner tested and is economical of fuel.

Persimmon, sassafras, and other kinds of tree sprouts and also stinging nettles (*Jatropha* sp.) are abundant in many east Texas fields, and removal of sprouts is a main annual task in crop production. Neither grubbing nor deep cultivation with powerful machinery is practicable on most farms. The Texas station found that a strong solution (2 pounds per gallon) of ammonium sulfamate poured on stumps of sprouts just after cutting off at, or just below, the soil surface prevented appearance of sprouts in most fields. Stinging nettles were nearly all killed by a single application of ammonium sulfamate (1 to 2 pounds per gallon) poured on the cut ends of the stems after the plant had been hoed out and a hole a few inches deep left.

FRUIT PRODUCTION

The war years saw large crops of fruits as well as other agricultural crops disposed of quickly at good prices. Quality of products was not always held at a high level, with the result that much low grade fruit found its way into the markets. With the return to a peacetime status and a normal demand, there is certain to be again a consumer market with insistence on quality. Much of the station work in recent years on fruits has been pointed toward the production of better-quality products, better in appearance, better in nutritive value, and better adapted for specific uses such as freezing preservation and processing. There have been some outstanding developments during the war period that will aid in the production of better fruits and in insuring its reaching the consumer in good condition. Among these developments has been the use of DDT to control codling moth and other insects and the development of large transport planes that can rapidly carry crops to consumer centers.

Varietal improvement by hybridization and selection has made definite progress in recent years.

Three new sweet cherries from the Idaho station, namely, Lamida, Ebony, and Spalding, were originated in an attempt to produce varieties, the fruit of which would not crack so easily during rains at harvesttime. The Lamida is said to resemble closely the popular Lambert cherry and to be far superior in resistance to cracking. Spalding, because of its exceptionally firm flesh, appears promising for long distance shipment.

From the Illinois station came a series of new peaches, resulting from a program of scientific breeding. Named Prairie Dawn, Prairie Sunrise, Prairie Daybreak, Prairie Rose, Prairie Schooner, Prairie Clipper, and Prairie Rambler, the new peaches cover the season from early to late and promise much for midwestern peach growers.

New early peaches, Early East and Jerseyland, from the New Jersey station promise much as early varieties to open the season and Jerseyland is expected to replace Golden Jubilee, an earlier product of the station breeding program. In addition the station named a new mid-season variety, Redcrest, so named because of its all-over red color attained while the fruit is still in good shipping condition.

Perlette, a new seedless grape originated by the California station, is the earliest maturing seedless grape in California. Perlette is said not to be equal to Thompson Seedless in quality but, because of its earlier maturity, is expected to become important in certain areas where time of ripening is of peculiar significance. Perlette should prove to be desirable in home gardens.

Catskill, a strawberry originated some years ago by the New York State station and now one of the two leading commercial kinds in the State, was found by the station to be very high in vitamin C (ascorbic acid). Some evidence was obtained that sunlight is also an important factor in vitamin C development. Berries grown in full sunlight were higher in vitamin C in any given variety than those produced under shade.

Massey, a product of North Carolina station and Department breeding, is becoming a valuable commercial variety in North Carolina. In the spring of 1946, Massey commanded a premium of about \$1.50 a crate on the important Wallace market over older varieties such as Klondike. Massey has large attractive fruits that ship well and please the consumer.

Delicious apples were found by the Wisconsin station to have a peculiar floral structure with short pistils that honeybees may not always pollinate when gathering nectar. Bumblebees, on the other hand, crawl over the blooms in such a manner as to effect satisfactory pollination of this variety. Favorable pollination may be expected with adequate bumblebees, a nearby pollen source from an effective variety such as McIntosh, or a very heavy honeybee population.

Progress was recorded by the Texas station in the breeding of new peaches that would combine late blooming to escape early spring frosts and adaptation to mild winter climates that fail to break the rest period of ordinary varieties such as Elberta. The promising seedlings were obtained from crosses of commercial varieties with honey types.

Calville Blanc, a variety of apple of European origin, was found by the New York State station to have the highest vitamin C content of any of the varieties and seedlings under test. The apple is described as of mediocre quality but offering possibility as a parent of new kinds rich in vitamin C.

Nutrition studies of fruits yielded important new information. Water may not be considered a nutrient but since nutrients are available to plants only when in a water solution, sufficient water is of a major importance in the feeding of plants. According to studies by the Ohio station moderate irrigation increased the fruit size of Rome Beauty apples by 25 to 30 percent over trees subjected to natural rainfall. Furthermore, the apples from the irrigated trees were better colored and of higher quality. The results suggest the value of moisture-conserving practices in fruit production.

Apple trees may be maintained in a vigorous productive condition according to the Indiana station by growing them in a well-fertilized bluegrass sod and even more effectively by adding a mulch of organic material beneath the trees in addition to the sod.

The possibility of harmful effects of overfertilization of McIntosh apples with nitrogen was observed by the New York (Cornell) station. Studies in five New York orchards gave a strong indication that fruit firmness is decreased by excessive nitrogen applications to the soil. Such differences were more in evidence in fruits after storage than at harvest. There was some suggestion that large nitrogen applications may have increased brown core development in storage.

The observation by the Maine station that magnesium is deficient in a large percentage of Maine orchard soils led to control investigations in which it was found that three sprays of Epsom salts, 20 pounds to 100 gallons of water, were effective where magnesium deficiency had reached the point of causing leaf injury. Orchards not showing injury but low in magnesium may be treated with magnesium limestone. The three-spray treatment program with Epsom salts at the rate of 20 pounds of salts per 100 gallons of water was also found effective by the Massachusetts station in preventing the appearance in the year of application of scorched leaves in magnesium-deficient apple trees. Some indication was obtained by the New York (Cornell) station that if magnesium lime was worked into the soil beneath the apple tree it would have a more rapid influence on the magnesium content of the leaves and in the reduction of leaf scorch than if applied on the soil surface.

The time of applying ammonium sulfate to peach and prune trees was found by the California station to be of minor importance, nor was anything gained by divided applications.

Experiments conducted by the Ohio station with South Haven peach trees growing on a fertile Wooster silt loam soil showed that yields were directly proportional to the size of trees. Trees in the sod plots were smaller than in the cultivation plots due apparently to a lack of available nitrogen. There were no significant effects of soil treatment on blooming date, maturing date, quality, color of the fruit, or winter injury to wood or buds.

A combination of nitrogen and phosphorus was found by the Utah station to be the most effective of various fertilizer treatments applied to cherry orchards.

Boron is an essential requirement for the normal growth of citrus trees according to studies conducted by the California station at Riverside with young lemon and orange trees grown in cultural solutions.

On boron-deficient trees, the vessels of the woody tissues were often filled with gum and gum was found in the leaves and in the peel of the fruits.

Determinations by the California station at Los Angeles of nitrogen content of the wood, leaves, flowers, and fruit of Valencia orange trees dug at frequent and regular intervals over 2 years showed no marked fluctuations in nitrogen content except in the leaves and bark. Nearly one-half of the total nitrogen of the tree was in the leaves, about one-fourth in the trunk and branches, about one-fifth in the roots, and about one-tenth in the twigs and shoots. On soil well supplied with nitrogen, further additions did not result in an immediate increase in the tree.

Nitrogen was the only one of the principal nutrient elements to increase significantly the yield of grapefruit grown by the Arizona station at Yuma. The addition of mineral nitrogen increased consistently the yields as compared with no-nitrogen trees. Quality of fruit was not appreciably influenced by fertilizer treatment. The use of phosphorus or potassium singly or in combination with other elements had no effect on the fruiting behavior of the trees.

Potassium deficiency noted by the New York (Cornell) station in a vineyard in Monroe County, and evidenced by interveinal yellowing and marginal scorching of the leaves, was corrected partially by soil application of potash fertilizer. Of the affected varieties Delaware and Portland was most seriously scorched with much defoliation by harvesttime. Analyses in late September of the leaves of potassium-deficient plants showed very low potassium content and the soil beneath injured vines was also low in available potassium.

Analyses by the California station of Carignane grape shoots collected at different times in the year showed that the winter disappearance of starch is almost quantitatively accounted for by the appearance of an equivalent amount of sugar in the above-ground part of the vine. There was no evidence of winter conversion of starch to sugar in the roots.

Shelling of berries and the development of small berries observed in certain California grapes was found by the California station not to be due to zinc deficiency alone. In some vineyards a spray of zinc sulfate corrected shelling and in others it had no measurable effect. Apparently shelling has no simple cause but is a complex situation in which zinc is only one of the operating factors.

Blueberries, according to studies of the Michigan station, grow best in a soil the acidity of which ranges from pH 4.0 to 5.2, with the optimum between 4.5 and 4.8. Sulfur proved effective in lowering pH values to a favorable point, and with highly acid soils light applications of ground limestone proved helpful.

Complete fertilizer was found by the Arkansas station to be profitable for strawberries and in general the lower the inherent fertility of the soil, the greater were the returns from the use of fertilizers. Particularly on light soils, there were two critical periods each year when fertilizers were most valuable—directly after harvest to encourage new plant growth, and just prior to bloom for the benefit of the crop.

Research on apple rootstocks conducted by the Maine station has led to the development of a cooperative nursery which will supply more

than 10,000 trees to Maine orchardists in 1947. The trees are developed with intermediate stocks of Hibernial and Virginia Crab varieties of established cold resistance and ability to transmit capacity for increased production to varieties grafted thereon.

Malling II, a rootstock variety of English origin, was found by the West Virginia station cooperating with the Department to be very effective in producing apple trees of moderate size and good productivity, especially for Jonathan, Staymared, Starking, and Golden Delicious.

At the Michigan station tree size of the McIntosh apple was found to be significantly reduced by the use of Malling IX as the intermediate rootstock. McIntosh trees on Malling IX interstocks came into fruiting earlier and bore more highly colored fruits.

A native Iowa apple, known as Clark Dwarf, was found by the Iowa station to be useful in producing small and early bearing trees when used as the intermediate stock between strong seedlings and named varieties. Among varieties which did well on Clark Dwarf were Golden Delicious, Red Delicious, Jonathan, Grimes Golden, Secor, and Edgewood. Clark Dwarf has particular significance in the Prairie States because of a capacity to withstand temperatures as low as 25° F. below zero without injury.

The peach is known proverbially among horticulturists as a fruit extremely difficult to root from cuttings. Yet the New York (Cornell) station was able to obtain rapid and extensive rooting of softwood cuttings taken in winter from a greenhouse-grown peach tree. Cuttings from the same trees in July rooted only 2 percent. The new method should prove valuable to peach breeders and other scientific workers.

A new method of producing dwarf cherry trees was reported by the New York State station by the simple expedient of grafting the scion at a height of 26 inches from the root crown of the mahaleb understock. Both Giant sweet cherry and Montmorency sour cherry appeared fully congenial on mahaleb. It is suggested that this new method of propagation may yield dwarf cherry trees for the home garden to go along with dwarf apples and pears.

Mahaleb cherry was found by the Utah station to be a better rootstock for sweet cherries in Utah than mazzard, used largely in eastern United States. The mahaleb-rooted trees were larger, more productive after 9 years of age, and better anchored in the soil than were the mazzard-rooted trees of the same top varieties.

Delaware grapes growing near Hammondsport, N. Y., on a badly eroded soil, are doing better according to records obtained by the New York State station and this Department, when grafted on certain vigorous growing rootstocks than when on their own roots. The findings are of material significance because of the limited vigor of Delaware on its own roots and because of the high value of its fruit.

In Mississippi, in cooperation with the Department, Concord and Delaware grapes growing on Dog Ridge rootstocks were vigorous and productive as compared with vines on their own roots as shown in studies by the Mississippi station. Attractive yields were obtained when the vines were pruned lightly and the clusters thinned to prevent overbearing.

Rootstocks, according to work of the California station at Riverside, influence the percentage of peel as compared to flesh and juice of the Valencia orange and Marsh grapefruit. Marsh grapefruit produced from trees on trifoliate orange roots had 34.6 percent peel as compared with 49.2 percent in fruit from trees on rough lemon roots.

Blossom thinning is one of the newer developments in fruit production, the blooms in full crop years being thinned by the use of certain floricultural materials. Although this activity is still in the experimental stage, sufficient progress has been made to indicate ultimate success. Beside the objective of reducing the cost as compared with hand removal, there is the added advantage of promoting annual bearing in varieties of fruits that are typically biennial in fruiting habit.

The Michigan station reports that the sodium salt of naphthyleneacetic acid in concentrations varying from 5 to 15 p. p. m., depending on variety of apple under treatment, was satisfactory in removing a desirable portion of the flowers. The material caused very minor injury to the foliage and had an added advantage of being effective over a considerable period from just before full bloom up to a week or 10 days after petal fall. The greatest thinning effect occurred, however, when the flowers were in full bloom.

In search of a blossom-thinning agent that could be used without potential injury to the foliage, the Michigan station tried several materials including combinations of vegetable oils, paraffin wax, bentonite, and an emulsifying agent. One such material applied to a Duchess apple tree in full bloom gave promising results, with many fruit clusters reduced to a single fruit instead of multiples.

Thinning of peaches by striking the flowering branches with elm switches was compared by the Missouri station with sprays of a proprietary chemical known as Elgetol for the removal of excess flowers from heavy flowering 7-year-old Elberta peach trees. Both methods proved effective with switch thinning more laborious but with the advantage of requiring no investment for spraying equipment or materials.

Preharvest sprays of dilute solutions of certain growth-promoting substances to retard the early dropping of nearly mature fruits were quickly adopted by the practical grower. The practice was accepted even before all details were fully worked out so that considerable research is still in progress to gain a better understanding of varietal responses, temperature and other environmental effects, proper timing, etc.

Timing of preharvest sprays was found by the New York State station to be very important in the case of the McIntosh apple, a variety which has been shown by several workers to be particularly responsive to such sprays. The Kendall apple responded sharply to preharvest treatments with naphthaleneacetic acid. At a time when only 2 percent of the fruit remained on untreated Kendall trees, there was 87 percent of the crop attached to treated trees. In fact some of the apples remained on the trees long after attaining their optimum packing condition. The aerosol method of application appeared real promising for small trees.

The New Hampshire station investigated the effect of soil type, root growth, size of crop, and of different chemicals on the premature dropping of the McIntosh apple but was unable to associate differences in soil profile, root distribution, or number of roots with fruit dropping. No difference in available potassium, nitrogen, magnesium, or calcium in the soil could be associated with dropping. Spraying trees with borax retarded dropping appreciably. Thinning of fruits in the early season had no consistent effect in reducing the percentage of subsequent dropping.

In California, where the use of growth-promoting sprays is said to have become a standard practice in preventing the premature dropping of pears, the California station investigated the effect of such treatments on the behavior of pears in storage. Watery break-down occurred in Bartlett pears from both sprayed and unsprayed trees and led to the suggestion that hormone sprays should not be used to extend the harvest period beyond the normal picking season. Little break-down would have occurred if pears had been picked promptly and the fruit placed under adequate refrigeration.

Timeliness in picking has long been recognized as an important factor in obtaining the maximum eating and keeping quality in fruit. A colorimetric test for proper maturity of peaches and apricots was devised by the Maryland station. The method is based on the assumption that the chlorophyll of fruit disappears during ripening and the rate of chlorophyll disappearance is relatively constant in all varieties. The pigment of a measured sample of fruit was extracted repeatedly with ethyl ether and the final extract after centrifuging was examined with a spectrophotometer to measure light transmission. The results compared closely with taste tests for ripeness and gave promise of providing a more accurate method of determining proper maturity for harvest.

Observations by the Rhode Island station on the weight losses of five varieties of apples coated with various concentrations of protective waxes showed that the reduction in rate of transpiration was not constant throughout the storage period. With high concentrations of wax emulsions, there was a marked increase in transpiration rate immediately following treatment. Later the rate of the heavily waxed apple dropped below that of the lightly waxed and control apples. The effectiveness of low concentrations of wax increased with time and was more constant than that of high concentrations.

Various treatments of tree and of harvested fruits were studied by the New York (Cornell) station in an attempt to reduce the tendency of stored fruit to develop scald, a surface disorder characterized by browning of the outer cells of the fruits. Nitrogen applications to the soil did not have a material effect on subsequent scald development. Maturity of fruit at harvest was a factor in certain varieties, with the relatively immature apples developing more injury than riper ones, but the difference was not sufficient to provide control. A wax emulsion coating gave good results, equal to oiled paper on properly ripened fruits. The vapors given off by ripening apples increased scald on susceptible varieties and were best offset by conditioning the air of the storage chamber with activated carbon to which had been added bromine.

Almost complete prevention of storage scald was obtained by the Rhode Island station by exposing apples of several varieties to 50 percent of carbon dioxide for 5 days. The treated fruits were firmer at the end of several months than were the untreated. The carbon dioxide treatment cost only 2 cents a bushel. In addition to effect on the fruits, the carbon dioxide destroyed all rats in the storage rooms.

BETTER VEGETABLES

Breeding and selection of vegetables carried on by public and private research agencies have given American growers many valuable new varieties of vegetables over the years. In some instances the new varieties have meant the saving of an industry threatened with extinction by a plant disease. Notable examples were the development of virus-resistant cabbage in Wisconsin and mildew-resistant cantaloups in California. The food shortage of wartime and new knowledge of the importance of vegetables in the diet increased the demand for varieties adapted to specific areas and needs. There has been an imposing list of new varieties in recent years, many coming from the State stations.

The Wisconsin station, working with the Department, continued its vital work on yellows-resistant cabbage, releasing in February 1946 a resistant kind, Improved Wisconsin Ballhead, and increasing for 1947 distribution another resistant variety known as Improved Wisconsin All Seasons. The station also developed a new canning pea, Delwiche Commando, of good quality and fairly resistant to wilt, a devastating soil-borne infection.

A scab-resistant cucumber, Highmoor, distributed by the Maine station in 1945, has real value for commercial growers. A second resistant kind still under number as Maine No. 2 is deemed promising for home gardens.

A new heading lettuce, Imperial 410, was selected by the Arizona station and the Department for the important commercial lettuce area in the Salt River Valley. The head is crisp and compact and enfolded by broad wrapper leaves. Under Arizona conditions the lettuce shows considerable resistance to slime rot.

Imperial 456, a lettuce resulting from New York (Cornell) station and Department research, has proved valuable in New York because of its ability to form firm heads during summer weather. So great has been the demand for Imperial 456 seeds, that it cannot be satisfied. The new variety has helped restore a fading industry as shown by returns to State growers in 1945 of \$3,514,000 as compared with \$497,000 in 1937.

The Pennsylvania station has developed three new lettuces, Pennberg, Pennlake, and Great Lakes Selection, all of promise in eastern production. Great Lakes Selection produced 60 percent solid heads compared to 10 to 40 percent in ordinary commercial varieties.

Granite State, a new variety of muskmelon, was developed by the New Hampshire station and introduced for extensive trials in 1946. The variety has high quality and disease resistance, and because of early maturity can be grown in New Hampshire where high-quality melons are hard to grow.

Penn Wonder, a new pepper from the Pennsylvania station in 1946, produces thick-walled fruits of bright color and uniform blocky shape. The new variety is believed to be valuable for both home garden and commercial uses.

The tomato has proved to be one of America's most valuable and useful vegetables and a "must" in wartime and postwar gardens. FNC, a new variety of tomato developed by the Maine station for northern areas in the State where popular commercial varieties fail to ripen, is surprisingly early, of good flavor, and high in vitamin C, an important nutritive principle especially where there is a lack of fresh fruit.

From New York State station came a new tomato known as Geneva No. 1, which has the capacity of maturing most of its fruits before frost. The plant is small in size, determinate in growth habit, and potentially less productive than the usual commercial variety but by setting more plants per acre production can be increased to a satisfactory point.

Three new varieties of tomatoes developed by the Massachusetts station for resistance to leafmold were grown in some 15 commercial greenhouses in the Boston area in 1945 with great increase in production and income to the growers. The three varieties, Improved Bay State, Improved Vetomold-121, and Leafmold Resistant Waltham Forcing, were selected from hybrids that derive their resistance from a primitive-type tomato. Seed supplies have been quickly exhausted because of the demand. An apparent increase in the virulence of the leafmold fungus may make necessary the introduction of an even greater degree of resistance. This is being sought in crosses with the wild peruvianum tomato, which is practically immune to leafmold.

A promising new vegetable product, roasted squash seed, is forecast as a result of investigations by the Connecticut (State) station. A new squash with naked seeds protected only by a thin membranous green covering instead of the hard shell which surrounds ordinary squash seed, was developed by the station. Removal of the membrane reveals a smooth, attractive, pearly white kernel which when dried and roasted in its own delicious oil and then salted provides a tempting nut food high in flavor and nutritive value. The product, given the name "pepos," may have wide acceptance particularly in countries such as Mexico where squash seeds are already an accepted article of diet. In addition to pepos, a pressed cake left after oil extraction has potential value as a high protein stock feed.

Hybrid vegetables have an important place in current breeding programs. The great success attained by plant breeders with hybrid field corn has naturally created a keen interest in possibilities of utilizing the same genetic techniques in the improvement of other crop plants. Breeders logically turned their attention first to sweet corn, and new hybrid sweet corn like hybrid field corn has been replacing open field-pollinated varieties at a rapid rate. Data on production of sweet corn seed compiled by the Department show a total of 6,884,000 pounds produced in 1939 of which 2,402,000 pounds, or about 35 percent, were of hybrid varieties. The total production for 1946 is estimated at 15,985,000 pounds with hybrids amounting to 10,831,000 pounds or about 68 percent of the total. A substantial and increasing volume of this production is represented by hybrids developed by the

Connecticut (State) station. From a production of 10,000 pounds of seed of Connecticut hybrids in 1935, the production has grown to 2,700,000 pounds in 1946 as estimated by the station. Approximately 25 percent of the 1946 production of hybrid seed will be of Connecticut hybrids. Current work by the station to improve the quality and disease resistance of hybrid varieties is making good progress.

Various other State stations including Iowa, Indiana, Illinois, Maine, Ohio, and New Jersey have made substantial progress in improvement of sweet corn by use of the hybrid techniques. Hybrid varieties, developed by the Maine station to meet the rather exacting conditions of a short growing season, supply seed for fully one-half of the hybrid acreage in that State. Early Golden 113, a market type, and Northland, an early maturing garden type, are products of station breeding. An inbred, Maine 2, has been released to commercial growers as the male parent for a new canning hybrid.

Tomato hybridization is also receiving much attention by breeders. The potential value of hybrid tomatoes has long been recognized as indicated by a favorable report from the New York State station in 1912. Yet the practical difficulty of producing hybrid tomato seed has handicapped progress. According to information compiled by the Minnesota station presenting the summation of trials in five States, hybrid tomatoes produced an average of 32 percent more fruit than did commercial varieties.

Hope for a simpler method of producing hybrid tomato seed than by the present tedious processes of emasculation and pollination is offered by the California station which found male-sterile plants in fields of commercial canning varieties. The use of male-sterile plants as the seed-producing parent would do away with part of the task, namely, that of emasculation.

In vegetable culture the present high cost of manual labor has created interest in practices that might result in larger and better quality yields on an unit area.

Close spacing of carrot seedlings or seed was found by the Utah station to be an important factor in obtaining high yields of seed per acre.

Prompt planting upon removal from storage of mother carrot roots designed for seed production proved important in increasing the percentage of surviving plants, according to studies by the Idaho station. Where 0, 3, and 7 days were allowed to elapse between removal from storage and setting in the field, the yields of carrot seed were in the order of 944, 852, and 495 pounds per acre.

Interplanting of tomatoes with soybeans was found by the Illinois station to result in higher yields for both crops than when planted singly. When tomatoes were interplanted with field corn, the tomato yields were not increased over tomatoes planted alone but the quality of the tomato fruits was improved.

With greenhouse tomato crops the application of growth-promoting substances to the opening flowers of the early clusters, which often open during the early spring days when light is at low ebb, has been found by numerous research workers to give increased sets of tomatoes at the season when they have the highest sale value.

Increased light according to work of the Indiana station may produce the same effect in improving the early set of tomatoes as do the

growth-promoting substances now in general use. The light treatments begun while the young plants were still in the seedling stage caused an increased set on the first five clusters. For some unexplained reason the set on the later clusters was reduced by the light treatment leading to a suggestion that it may be possible to combine light and chemical treatments advantageously.

Snap bean yields may be increased by treatment with certain growth-promoting substances according to investigations conducted by the Missouri station. One application proved sufficient. Yield increases averaged 25 percent above the untreated. For some undetermined reason the same treatments had no benefit on peas, shell beans, or lima beans.

Beets showed a surprising response to soil applications of ordinary salt in studies conducted by the New York State station in 10 growers' fields in 1945. In every case the use of 500 pounds of salt per acre increased yields whether applied before planting or as a side dressing to the growing plants. Increases from salt were recorded even where nitrate of soda, another sodium salt, was used in the regular fertilizer.

Phosphorus fertilizers were found essential to lettuce in studies by the Arizona station. No difference was found between various sources of phosphorus provided they contained equal amounts of the essential element. The best program appeared to be the application of phosphates at time of planting with nitrogen applied later as a side dressing. The most successful way of applying phosphates was in a band approximately 1 inch wide, 3 inches below the seed, and 1.5 inches to the furrow side. On soils depleted of organic matter, corral manure gave better results than did chemical fertilizers.

Tomatoes respond well to heavy fertilizing according to work of the Indiana station conducted on a poor, light-colored soil. An application of 1,000 pounds per acre of a 2-16-8 NPK fertilizer on the plow sole plus 200 pounds in the row increased tomato yields about 4 tons per acre over those of plants receiving 400 pounds of 2-16-8 in the row.

Organic matter, in the form of animal manure, was found highly important for vegetables according to studies at the Alabama station. Lettuce, beets, and carrots proved particularly responsive to animal manures with members of the cabbage family less affected. Green vegetable manures were not equal to animal manure but a turned-under crop of cowpeas proved a valuable source of nitrogen for fall turnips.

Broadcasting and plowing down 1,200 pounds per acre of 5-10-10 fertilizer before setting the plants have given consistent yield increases of approximately 1 ton of tomatoes per acre in experiments by the Delaware station over yields obtained by the usual practice of broadcasting the fertilizer on top of the ground. These results, together with the closer spacing of plants, also found to increase yields by the station, were adopted by some 30 percent of Delaware growers in 1945 with an estimated increase in yield of 4,500 tons of tomatoes. At 1945 prices this increased production sold for \$180,000.

Phosphatic fertilizers, placed at a depth of 3 to 5 inches, gave excellent results with tomatoes in Utah station experiments. A combined treatment of manure and phosphate proved valuable also but nitrogenous materials used alone encouraged excessive vine growth with many large fruits, some of which failed to ripen before killing

frosts. The inherent fertility of the soil was a factor, with moderate amounts of nitrogen in addition to phosphates giving good results on soils of low fertility.

Nutritive value of carrots is affected by the season of planting according to the Oregon station which followed the carotene value in carrots planted at different seasons. Carrots grown during the winter period were much lower in carotene value than those grown in the summer months.

Storage of vegetables is an important task on the farm more particularly in northern areas where the long winters make imperative the storing of as much of the summer crops as possible.

Squash storage has presented a problem because of frequent occurrence of rots in the stored product. The New Hampshire station found that drying squash thoroughly during the first 2 weeks of storage is essential to good keeping. The storage should be heated to 80° F. and the air circulated, or the squash may be preheated in a greenhouse where natural temperatures may range up to 120° F. on warm sunny days. Complete removal of stems and avoidance of bruises are important. One New Hampshire grower stored 200 tons of squash in 1945 using methods developed by the station.

Tomatoes cannot be held for many days after harvest before softening and decay. As a result southern growers have developed a practice of harvesting the fruits when still a greenish-yellow color so that they will withstand shipment to northern markets. As a result of premature picking, southern tomatoes have never attained the high quality possible in this vegetable. The Florida station reports that a new type of pliofilm wrapper, highly diffusible to carbon dioxide, kept tomatoes in good condition much longer than the usual wrapper. As a result, tomatoes may be left on the vines longer and thereby attain a quality not possible in the greener fruits. This new procedure should do much to make southern-grown tomatoes more popular to northern consumers.

Sweet corn is difficult to harvest at the point of optimum maturity. The Maryland station developed an instrument known as a succulometer, which removes the readily extractable juice from a measured sample of sweet corn kernels under hydraulic pressure. The volume of extractable juice under an established set of conditions corresponded closely with the result of taste tests and has the advantage of greater accuracy. The new instrument has potential value to the producer, the canner, and the plant breeder.

Packaged tomatoes, beans, spinach, parsnips, potatoes, apples, and grapes protected by a wax emulsion and covered with porous cellophane were observed by the Indiana station to keep in better condition when exposed to sales conditions than did the same produce handled in bulk. Losses were greatly reduced and the added cost was accepted cheerfully by the purchaser. General use of the new procedure should increase sales and give the consumer a better quality product.

FORESTRY INVESTIGATIONS

Successful establishment of eastern white pine on light sandy soils was achieved by the Illinois station by setting 2-0 stock with planting bars in contoured furrows. On heavy prairie soils conifers made very rapid growth in their first 25 to 30 years, followed by a rapid decline

in growth and quality which indicated that conifers are not suited for timber production on such heavy fertile soils. Jack pines on light-sandy soil attained a Christmas-tree size in 3 to 4 years.

Certain unusual conifers, notably Japanese Black pine, Japanese red pine, and digger pine, were found by the Oklahoma station to be well adapted for planting in the State. Japanese black pine appeared unusually promising because of high survival at time of planting and an apparent immunity to pine tip moth. The introduction of native shortleaf pine into native oak stands growing on light soil appeared feasible, thus increasing the value of much land which is now producing little or no income.

Reconversion of inferior hardwood stands to worth-while pines is recommended by the Alabama station as a result of extensive plantation studies. The pines can be planted among the hardwoods and then some 3 or 4 years later the hardwoods removed with some return from fuel wood. Fire control is of great importance in the successful growth of loblolly and shortleaf pines. Fertilizers increased the diameter increment of slash pine.

Woods impregnated with asphalt from which the creosote fraction had been removed were found safe by the Massachusetts station for use in plant frames, greenhouse benches, and seed flats. Various other wood preservatives were found to cause serious injury to plants. Wood treatment made possible the use of supposedly inferior species to replace scarce and costly species, such as cypress, which was formerly used in constructing plant bed equipment.

A satisfactory substitute for chestnut, the wood used formerly for posts to support shade covering of tobacco fields, was found by the Connecticut (State) station by the simple expedient of treating the butts of logs in hot and cool creosote. The treated post lasted 15 years or more as compared with a maximum of 5 years for the untreated. Freshly cut posts treated by the sap stream method with zinc chloride showed much promise and made possible the use of naturally inferior woods.

SOIL PRODUCTIVITY INCREASE AND MAINTENANCE

The end of war brought about a lessening of the pressure of demand on many of our natural resources that were essential in making the machines needed for victory. As far as the demand on another important resource, namely, our soil, is concerned, the end of combat brought into clearer focus the requirements, both immediate and future, for feed and food production that will call for continued maximum utilization of our soils. Thus, one of the aftereffects of war represented by the unprecedented demand for food, which must come directly or indirectly from our reserve of soil fertility resulted in the continuing search for and application of research findings about our soils that might accomplish increased production with maximum conservation as well as restoration of fertility for future production.

Available information indicates that intensified soil management may be followed without serious decline in crop yield or loss of soil fertility on only limited soil areas. Under most soil conditions the past few years of maximum production likewise have shown the importance of proper management. To this end, workers in soil science continued their efforts toward developing systems of soil

management that provide the necessary soil-building practices to accomplish as nearly as possible a system of permanent agriculture. Results from long-time soil management investigations as well as facts from chemical, biological, and physical research with soils along with current short-period studies to determine the best practice under any particular local condition continued to provide needed information. Some of the findings of soil scientists that have contributed to increased or more efficient production through new or modified systems of soil management will be considered in the following brief review.

SOIL MANAGEMENT

The importance of good soil and good soil management in relation to crop yields and soil fertility maintenance is illustrated by the results of investigations from several experiment stations to determine nature of crop rotations, grass and legume crops in fertility maintenance, and the use of rotations combined with commercial fertilizers and liming. For example, the results of 35 years of soil treatments on a poor and on a good soil by the Illinois station show that the soil alone, especially a poor soil, contributed a smaller and smaller share of crop yields over the years. On a poor soil a complete treatment consisting of the use of crop residues, limestone, rock phosphate, and potash produced an average yearly income per acre for the 35-year period 1910-44 of \$18.89, while under a system involving no soil treatment the yearly return was only \$3.97. On one of the most productive soils, good land treatments are responsible for a much smaller share of crop yields than they are on the poor land. For the good soil average yearly income for the period indicated above for the complete soil treatment was \$26.10, while with no treatment the return was \$23.32.

Under Mississippi conditions, according to results from the Mississippi station, fertile soils likewise gave the greatest profit. From a survey of the effect of soil fertility and management on profit from cotton production, the station found that the inherent soil fertility governs the production on each soil type but that management determines what percentage of the inherent productive capacity is realized. The average profit obtained from farms with good soil was \$61 per acre from cotton. With farms that were classified as having a low level of soil fertility, the profit obtained averaged only \$12 per acre. Farms intermediate in soil fertility were likewise intermediate in income.

Rotation experiments with a sweetclover catch crop by the Ohio station point the way to raising grain every year and still maintaining soil productivity. Experiments comparing the 2-year rotation of small grain one year, corn the next, without a clover catch crop, with the same rotation with a sweetclover catch crop sown in the small grain and plowed down for corn have shown that on Miami silty clay loam one crop of sweetclover plowed under increased the yield of corn 18.6 bushels per acre. On Brookston clay, plots in the 2-year rotation have been continued with and without sweetclover since 1930. For the last 7 years of the test, the plots with sweetclover plowed down May 1 have averaged 20.1 bushels more corn per acre than the plots without sweetclover. The oats in the rotation averaged 7 bushels more each year in the same period.

The value of soil management under eastern Great Plains conditions where the use of fertilizers has not become very extensive is illustrated by results of field experiments from the North Dakota station, where corn yields were increased from 51 to 65 bushels per acre through the use of manure and from 51 to 72 bushels per acre with manure and phosphate. The residual effect of these treatments on the succeeding wheat crop was greater than for the direct application to corn, the check plot averaging 29.0 bushels, the manured plot 35.6, and the manure plus phosphate 38.0 bushels per acre.

Rotations and soil treatments have been found necessary for maintaining high yields in the Corn Belt. From a 30-year study with various rotations, the Iowa station reported that the yield of corn, for example, in a 4-year rotation of corn, corn, oats, and mixed hay was 51.7 bushels per acre without any soil treatment, while the yield where corn has been grown continuously was 37.9 bushels per acre. Fertilizer treatment in the various rotations increased the yield of corn but did not take the place of the rotation system. When the rotation was corn and oats and the soil treatment was manure, lime, and rock phosphate, the corn yield was 55.2 bushels per acre; but when the rotation was corn, oats, clover, wheat, alfalfa, and the soil treatment the same, the corn yield was 92.8 bushels per acre.

MORE EFFICIENT USE OF FERTILIZERS

Fertilizers continued to play a role of ever-increasing importance in the attainment of the high production goals established during the war years. With fertilizer consumption in the United States for the year 1945 of over 13 million tons, the significance of efficient fertilizer use becomes clearly evident. Based upon response with various crops under many different soil and climatic conditions, it has been estimated that 20 percent of the food grown in this country is directly due to the use of fertilizers. The records of increased crop yields obtained from fertilizer use by the experiment stations are well recognized and many, and consideration in this report will only be given to the findings that reveal new principles or illustrate methods of more efficient fertilizer use.

Greater efficiency in the use of available supplies of potato fertilizer has resulted from cooperative investigations by the Alabama, Maine, Maryland, North Carolina, New Jersey, New York (Cornell), and Virginia Truck stations and the Department. From field plot and laboratory studies of soils used for commercial potato production, it was found that there was an accumulation of readily soluble phosphorus and that the exchangeable potassium content of many of the soils in the several States had been greatly increased by fertilization. From the standpoint of fertilizer practices on potato soils having over 500 pounds of soluble phosphorus per acre, further applications by 40-pound increments did not give a significant increase in yield. Chemical studies of exchangeable potash in the soil in relation to potato yields indicated that on soils containing large amounts of exchangeable potash little or no increase in yield occurred with potash applications greater than the rate of 100 pounds per acre. Thus, with information on the plant nutrient requirements of the potato crop, and on the plant nutrient supply in the soil, it has been possible to put the use of fertilizers for potato production on a rational basis.

Alfalfa-producing areas were benefited by the use of phosphate fertilizer, according to results reported from the Idaho station, where experiments showed that adding phosphate to soils low in available phosphorus in the course of a 6-year rotation gave greatly increased returns. For example, the addition of as little as 350 pounds of phosphate per acre applied in two applications resulted in increasing the value of the alfalfa crop over 3 years by \$60 per acre. Two crops of potatoes gained \$54 per acre and one crop of wheat \$8.70 per acre. Subtracting \$9.10 for the cost of fertilizer, the net gain amounted to \$113.60 per acre over the 6-year rotation period. In addition, the protein and phosphorus content of the alfalfa hay was improved, making it more valuable to stockmen for animal feeding.

Phosphorus and potash were found essential for nitrogen fixation from applications of these nutrients by the Indiana station to cereals in rotations with legumes on several Indiana soil types which resulted in nitrogen gains in the soil of from 2 to 40 pounds. Chemical studies indicated that phosphorus deficiency inhibits nitrogen fixation by inhibiting protein synthesis and causing accumulation of products of nitrogen fixation. Potash deficiency apparently inhibits nitrogen fixation by limiting the supply of carbohydrate to the nodules.

Nitrogen fertilizer was found to be a good investment by the Mississippi station. More than 20 years of experiments in all sections of the State have shown that nitrogen returns \$4 to \$5 worth of corn for each dollar spent for fertilizer used on it. This is about the same rate of returns as received from fertilizer used on cotton. The yield of corn could be increased from the 15-bushel State average to 25 bushels if each acre were fertilized with 24 to 32 pounds of nitrogen.

Nitrogen maintained quality and increased the yield of peas in experiments reported by the New York State station, where liberal use of sulfate of ammonia, ammonium nitrate, or nitrate of soda gave marked increases in yield and kept peas in fancy grade for a longer period. The use of ammonium sulfate at the rate of 300 pounds per acre increased the yield of peas from 2,660 to 3,736 pounds per acre. With the use of both limestone and ammonium sulfate, the yield was increased to 4,098 pounds per acre. The increase in yield and quality due to the fertilizer treatment was more than adequate to cover the cost of fertilizers.

Leaching losses of nitrogen were substantially reduced through the use of winter legumes by the California station. From experiments extending over a 10-year period under controlled conditions, the station found that leaching and decomposition losses of nitrogen ranged from 75 to 150 pounds per acre, depending on the cropping system used. The growing of winter legume crops, such as sourclover (*Melilotus indica*) or purple vetch, was found to add, through nitrogen fixation, about 100 pounds of nitrogen per year. The use of 200 pounds per acre of nitrogen fertilizer required in citrus culture resulted in a reduction of approximately 50 percent in nitrogen fixed by the legume crop. Even with this reduction in amount of nitrogen fixed by the legumes, reduced expenditures for nitrogen fertilizers resulted.

Anhydrous ammonia, one of the cheapest sources of nitrogen, was investigated by the Mississippi and New Jersey stations. When applied in the fall under Mississippi conditions, anhydrous ammonia

made approximately twice as much increase in yield as ammonium nitrate. On the average, spring application of ammonium nitrate was superior to anhydrous ammonia applied in the fall. Anhydrous ammonia applied in the fall was equal or superior to spring application of ammonium nitrate on soils which had a low rate of nitrification; on soils with a high rate of nitrification spring application of ammonium nitrate was superior to fall application of anhydrous ammonia. Observations were made which suggest that fall-planted oats do not use the nitrogen in ammonium form in the spring. Spring application of anhydrous ammonia was entirely satisfactory for oats when applied sufficiently early for nitrification to take place. When used in solution of one part ammonia and three parts water and applied as a top dressing on pasture grasses, the New Jersey station reported that the foliage of the grasses was burned and the anhydrous ammonia was much less effective than standard nitrogen carriers. With this system of application a considerable amount of the ammonia undoubtedly escaped into the air. When the ammonia solution was dropped on the bottom of the furrow immediately ahead of the plow, however, it produced as good results as the same amount of nitrogen in the form of ammonium nitrate.

Potassium content of the alfalfa plant served as a basis for determining potash need and response in studies by the New York (Cornell) station. From field experiments with alfalfa, it was found by leaf diagnosis for potash that when the potash content was less than 1.3 percent at early bloom stage, yield increases of about 20 percent were obtained with potash fertilization. With plants that showed a potassium content of more than 1.3 percent, added potash seldom gave increases in yield. Thus, the use of leaf diagnosis to determine the relationship of yield to nutrition with respect to major nutrients is providing a basis for greater efficiency in fertilizer use.

Potash deficiency in growing corn was corrected and greater yield obtained by the Tennessee station by the application of 50 to 100 pounds of potassium chloride 40 days after planting. Application of potash 59 days after planting also corrected the deficiency but did not significantly affect yield, whereas applications 79 days after planting resulted in the least improvement.

The relation of potassium and magnesium supply to such factors as fruit shedding in September, fruit development, and yield and quality of soybeans was investigated by the North Carolina station to determine if fertilizer practices could be developed that would result in increased production of better quality soybeans. Potash at the rate of 60 pounds per acre increased the percentage of seed cavities filled from 60 to 78 percent, decreased fruit shedding in September, and decreased the percentage of poor quality beans from 37 to 3 percent. All of these factors contributed to increased yields. The response to magnesium was not as marked as the response from potash.

Sodium continued to be useful in cotton production, according to further results from the South Carolina station during the present period of limited potash supplies. The addition of sodium may materially increase the yield of cotton where it is possible to make only a light application of potash, and certain combinations of potassium and sodium are as effective as equivalent quantities of potassium. For example, the station found that 30 pounds of potash in combina-

tion with sodium gave practically as high a production as 40 pounds of potash alone. A 25-pound application of potash plus a side dressing of nitrate of soda produced a higher yield than 30 pounds of potash without sodium nitrate as a side dressing.

The Alabama, Georgia, Mississippi, and South Carolina stations continued to show the importance of the use of lime in cotton production. For example, the Georgia station, from extensive studies, found that the use of 1,000 pounds of dolomitic limestone resulted in an average increase of about 70 pounds of seed cotton per acre. Under some soil conditions, the yield increase was as much as 186 pounds per acre. The Georgia results as well as results in other Southern States indicate that soils with a high potash content respond better to lime than soils low in potash.

Experiments by the North Carolina station showed early spring applications of ground limestone to give the best response on peanuts. This system of application also fits more readily into the peanut production program, and general use of the practice would mean a considerable saving to growers.

The Wisconsin station found that liming to pH 6.5 was the most desirable lime level for general farming. At this lime level available phosphorus was highest and conditions were favorable for an adequate supply of available boron. Mixing of phosphate with lime prior to application resulted in somewhat better yields and a higher level of available phosphorus than where the two materials were used separately. In related studies on different lime levels, the Maryland station found a considerable influence on crop yields as measured by a 3-year rotation of corn, small grain, and hay. Corn yields have been considerably higher at the 5.5 pH level, with a 7.5 level being the lowest. A heavy application of phosphoric acid and potash and even nitrogen did not overcome entirely the depressing effect of lime upon corn yields; however, the depressing effect was greatly diminished.

The relation of soil-plant nutrient supply and number of plants per acre in corn production was shown from results by the Pennsylvania station. With 7,100 plants per acre the yield was 68 bushels. When the same number of plants was fertilized with 600 pounds of a 10-10-10 fertilizer, the yield was increased to 71 bushels per acre. Increasing the number of plants to 17,700 gave a yield of 77 bushels per acre without fertilizer and 97 bushels per acre when treated with 600 pounds of fertilizer.

Investigations of fertilizer needs of soils in the Matanuska Valley by the Alaska station showed that the lowest rate of complete fertilizer amounting to 15 pounds nitrogen, 20 pounds phosphoric acid, and 20 pounds potash per acre resulted in an average increase over areas not fertilized of 112 bushels of potatoes per acre. With the highest rate of fertilizer, consisting of 45 pounds nitrogen, 60 pounds phosphorus, and 60 pounds potash, the yield exceeded the no-fertilizer plots by 212 bushels per acre. On the basis of the average increase of 155 bushels per acre, the station has determined that the farmer would benefit to the amount of \$100 per acre through the proper use of fertilizers.

The importance of fertilizers in obtaining increased production under soil conditions where the need for plant nutrients beyond the

supply present in the soil has not been long recognized was likewise indicated by results from the South Dakota station. Experimental plots were located so as to be representative of major crop and soil areas. The average increase for oats receiving fertilizer treatment according to need of the crop was from 55 to 86 bushels per acre, for corn from 49 to 60 bushels per acre, for potatoes 162 to 244 bushels per acre, and for grass seed from 82 to 157 pounds per acre.

Plow sole application of fertilizer was found to be effective for sugar beets by the Wisconsin station where yields averaged about 11.5 tons to the acre with 150 pounds 3-12-12 fertilizer and 7.5 pounds borax drilled along the row. The yields jumped to more than 15 tons where the same row treatment was used along with 1,000 pounds 6-6-20 either plowed under or broadcast. Best yields of nearly 17 tons were secured where 800 pounds 8-8-8 and 300 pounds 0-0-60 were either plowed under or broadcast to supplement the regular row fertilization.

Experiments by the Mississippi station showed that plow sole application produced a significantly higher yield of cotton and corn than the furrow, side-dress, or deep methods of application.

Drilling, plowing under, banding, pelleting, and applying with organic materials were among different methods studied by the Vermont station in attempting to find more efficient methods of fertilizer use. Results indicated that limestone, potash, phosphorus, and boron could very well be applied with the manure, since manure was found to reduce the amount of phosphorus and possibly other plant nutrients that become fixed in an unavailable form in the soil.

The Florida station, in reviewing the results of its research on trace elements as applied to the problems of Florida agriculture, points out that the extensive production of vegetables in the Everglades would not have been possible without the use of these materials. Moreover, their widespread use to keep citrus groves in a thrifty condition has greatly increased the quality and value of the fruit and the tolerance of the trees to cold. Now 60 percent of the beans, 24 of the cabbage, 35 of the celery, 80 of the peas, and 18 percent of the peppers grown in all Florida are produced in one county where little was harvested 20 years ago because of trace element deficiencies. Some 30 million additional boxes of citrus fruit are produced annually as a result of research in trace elements begun about 10 years ago. Trace elements are applied in relatively small amounts ranging from about 10 pounds of boron per acre to some 40 or 50 pounds of manganese and copper. The figures on their use for agricultural purposes in Florida are therefore a good basis for showing the extensive application of the research findings of the experiment station. During a 12-month period Florida farmers use some borax, about $3\frac{1}{2}$ million pounds of zinc sulfate, about 19 million pounds of copper sulfate, nearly 23 million pounds of manganese sulfate, and large quantities of magnesium. About 70 percent of all the manganese used for agricultural purposes in the United States is used in Florida.

The amount of illumination was found to affect the requirements of plants for boron and zinc in studies reported by the California station. Nutrient-conducting tissues were adversely affected in boron-deficient plants, with a resultant slowing up of transport of nutritive material and the formation of substances harmful to the cell. Also,

the course of carbohydrate transformations and phosphate metabolism was found to be arrested or diverted in case of boron or zinc deficiency.

Continuing work with minor elements on organic soils, the Michigan station reported on the relationship between zinc, copper, and manganese for spinach, onions, and Sudan grass. Under field conditions, a significant difference in absorption was obtained when the elements were added to the soil. The percentage composition of other elements was not appreciably affected. In the greenhouse it was found that the addition of one minor element affects the absorption of other elements. These results are similar to those reported from other stations with different elements.

From leaf analysis studies of plant nutrient levels and chemical composition of soils associated with various growth conditions, the Oregon station has found the use of certain minor elements to be especially important in successful small fruit production. For example, zinc sulfate applied at the rate of 30 pounds per acre once in 2 years caused a 5-year average increase in net profit of \$110.33 per acre with red raspberries on Powell silt loam and \$76 with gooseberries on Amity silty clay loam.

The New York (Cornell) station conducted investigations to determine whether or not soils would supply the boron required for the production of a normal crop of alfalfa by determining the boron content of alfalfa hay and the water-soluble content of boron in soils. Both methods were compared against symptoms of boron deficiency and the limits of boron content in the hay and soil associated with deficiency conditions. The workers concluded that boron deficiency could be predicted more accurately from total boron in the hay than from the water-soluble boron in soils.

From long-time experiments on the effect of different soil treatments on boron deficiency, the Connecticut (Storrs) station reported that borax at 20 pounds per acre in 1938, and none since, has almost entirely prevented the appearance of boron deficiency symptoms and increased the boron in the alfalfa 60 percent through 1944. To that time, the boron removed in the 12 tons of dry matter harvested was about 40 percent of that added in the 20 pounds of borax. Manure at 10 tons annually reduced the prevalence of boron deficiency nearly 50 percent but increased the boron content of the alfalfa by only 8 percent.

The Washington station reported that an insufficient amount of sulfur for successful alfalfa production on certain soil types of the State has made it necessary to supply this element before the need or the response to phosphorus or potash can be measured.

Chemical studies of selenium and arsenic in various geological formations by the South Dakota station are providing information that greatly reduces the possibility of selenium poisoning of livestock. The content of arsenic in the soil is an important factor because of the action of arsenic in counteracting the effect of selenium.

SOIL PROPERTIES THAT INFLUENCE USE AND PRODUCTIVITY

Investigations of soil structure, amount and movement of air and moisture in the soil, as well as additional information on other physical properties of the soil continue to show that the supply of plant nutrients in a soil may be misleading if used as the only index of crop-

producing capacity. The production of grain crops during the war period has resulted in lower yields than would be expected from the standpoint of decline in soil nutrient supply alone. This is indicated by studies at the Ohio station where the excessive growing of such crops as corn, soybeans, and oats has reduced corn yields nearly 50 percent during a 7-year period. In contrast, growing the row-crop corn in 3- and 4-year rotations including 1 or 2 years of soil-rejuvenating sod crops has raised unfertilized corn yields from 50 to 68 bushels per acre. Highest corn yields have been obtained following 2-year-old alfalfa-bromegrass sods which bring about maximum increase in water-stable granulation, improved soil aeration and drainage, and a general restoration of those favorable soil physical conditions associated with soil productivity.

The importance of proper physical condition of the soil to plant growth is also illustrated from experiments by the Iowa station in greenhouse studies with two soils to determine the effect of soil aeration when modified by changes in soil moisture and amount of pore space. Results indicated that increasing the soil moisture content to 40 or 50 percent reduced root and top growth and lowered the nutrient absorption of potash, phosphorus, nitrogen, calcium, and magnesium. Reduction of total pore space by compaction of the soil likewise decreased the amount of root and top growth and reduced the total content of all five elements in the plant. When air was forced intermittently through the soils, a marked increase in growth resulted and the total nutrient uptake by the plant was higher. There was a closer relationship between potassium absorption by the plant and the condition of soil aeration than in the case of the other elements studied. Potash and phosphate fertilizers added to the soils under study helped to alleviate the effect of poor soil aeration on plant growth.

In related studies under field conditions, the Iowa station and the Department found the method of seedbed preparation to have a marked effect on nutrient deficiency conditions in corn on Tama soil. Where no fertilizer was applied there was little evidence of nitrogen deficiency in corn on plowed soil, whereas on listed, disked, and subsurface-tilled soil nitrogen deficiency was quite marked, especially under the latter two treatments. Corn yields on the variously tilled soil where no fertilizer was applied were directly related to the data obtained on nitrogen deficiency, the yield of plowed corn being 18 bushels per acre higher than the average of yields of 37 bushels per acre obtained where the soil was tilled by the other three methods. Fertilizer containing nitrogen increased yields under all tillage methods except plowing. Under the last-named treatment, there was no nitrogen deficiency.

The effect of different crops on soil structure and crop yield when grown in various rotations was the objective of investigations by the Rhode Island station. From 3-year rotations including onions and 5-year rotations including corn and potatoes, the workers found that onions and mangels had a deleterious effect upon soil structure whereas redtop was beneficial. Corn and buckwheat aggregated the soils slightly more than onions or mangels. The yield of onions was found to be directly related to the state of aggregation of the soil. In the corn-potato-hay rotations, soil aggregation under leguminous hay crops was greater in the fall and less in the spring than under non-

leguminous hay crops. Potatoes and corn were deleterious to the soil structure, whereas the hay crops were beneficial.

Soil structure, reflected by the extent of aggregation in relation to organic matter content, was found to reach a maximum when the organic matter was increased to 2 percent under experimental conditions in Lintonia silt loam soil by the Louisiana station. This information is useful in selecting cropping practices that provide for a maintenance of soil organic matter of the desirable percentage.

SOIL AND MOISTURE CONSERVATION

Effect of tillage method including stubble mulch tillage on soil and moisture conservation and yield of wheat under northern Great Plains conditions was reported by the North Dakota station and the Department. The storage of soil moisture, either under continuous cropping or on summer fallow, has not been greatly affected by type of tillage. When tillage was for seedbed preparation under continuous cropping to wheat, a somewhat lower yield was obtained from stubble mulch tillage than from other tillage methods. This was particularly true at one location where there was a significant decrease in yield with increase in the extent to which residues were left at the surface. At another location, though stubble mulch tillage produced a lower mean yield than plowing, these two methods produced the same yields during 3 of the 6 years of trial. From the standpoint of yield, stubble-mulch tillage has proved as satisfactory as other methods of tillage for summer fallow and, in addition, controls erosion and aids in maintaining soil productivity.

On the loessial soils of the lower Mississippi, the Louisiana station and the Department found subsoil tillage, reversing the rows in the fall, and use of winter cover crop greatly reduced soil losses and increased the yield of the corn crop following. Reversing the rows and subsoiling decreased the runoff 22 percent and increased yield 51 percent, the use of a winter cover crop reduced runoff 27 percent and increased yield 97 percent, and subsoiling plus a winter cover crop reduced runoff 50 percent and increased yield 167 percent.

Sod crops pay when land is again returned to vegetable production, according to experiments reported by the New Jersey station and the Department. Four years' results have shown that the use of sod-producing crops, which is not a common practice under intensive vegetable production, increased yields of peas, beets, rutabagas, sweet corn, tomatoes, and field corn. For example, a 2-year clover and timothy sod produced 60 percent more tomatoes than were produced on an area with a good winter cover crop but cultivated during the previous summer. These results indicate that when it becomes necessary for farmers to reduce acreages of cultivated crops because of decreased demand, potential production capacity in addition to protection from erosion can be given to soils through the use of sod crops.

Use of improved soil management and soil conservation practices on Indiana soils by the Indiana station and the Department improved soil structure, increased water absorption, reduced erosion, and increased yields. The yield of corn from plots managed according to prevailing methods was 66 bushels per acre and 91 bushels on the improved-method plots. Hay showed an increase of 1,089 pounds

per acre over the prevailing-method plots. With increased yields the unit cost of production was lowered on the improved-practice plots.

Time of tillage in areas of low rainfall was found to be important by the Oklahoma station, where investigations indicated little difference in the yields obtained from the different methods of tillage employed. But, regardless of the method of tillage used, yields were decreased as the operations were delayed. On the appreciably heavier sandy types of soil where wheat was grown for 13 years, the average yield of all early methods of tillage, 17.2 bushels per acre, was 1.5 bushels greater than midseason tillage and 5.0 bushels per acre more than the average yield for all late methods of tillage. The information presented warrants the assumption that the wheat grower in northwestern Oklahoma who does a good, workmanlike job of preparing a seedbed early in the season, regardless of the method used, stands to gain much more than the man who delays such work.

Crop residue utilization practices for erosion control developed by the Nebraska station and the Department are spreading rapidly on farms in the Great Plains area of the United States and Canada. Workers at the station have estimated that for the State of Nebraska over 400,000 acres are subjected to some form of crop residue protection. Continuing studies on the possibilities and limitations of crop residues on the surface for evaporation control, the workers reported from tests conducted from January 15 to May 15, 1945, that the comparative, total evaporation losses from residue-covered and bare soil were 2.78 and 5.98 inches. Total savings due to residues as reflected in subsoil storage amounted to 2.96 inches. The rainfall of the period was 8.40 inches. Its efficiency from the standpoint of storage was more than doubled through the use of residues. In general, however, evaporation control through residues on the surface has been great during cool seasons rather than hot; following large rains rather than small, or during periods of persistent wetness; and it has been great at any time only in proportion to the thoroughness with which the soil is covered and shaded. Quantities of residues that only incompletely cover the soil are much more effective relatively as runoff reduction and erosion control than at evaporation control.

The extent to which certain tillage and crop residue utilization practices can be used in various sections of the country is not fully known and must be investigated under local conditions. The Virginia station and the Department, for example, found that corn yields were highest on turnplow areas, intermediate with the turnplow and sweep, and lowest where the soil was disked. Modified practices showed that combinations of ripping or sweeps together with moderate disking gave highest yields with a moderate weed problem. Studies of available nutrients in the soil indicated that they followed the same pattern as crop yields. While the use of stubble mulch greatly reduced erosion, the amount of available nitrogen was also greatly reduced.

Utilization of sugarcane trash as a mulch on steep slopes devoted to sugarcane production by the Puerto Rico University station reduced soil losses in runoff water to 1.22 tons per acre per year, whereas unmulched soils under similar conditions lost 16.17 tons of soil per acre per year. On this basis it was estimated that the mulching practice would prevent the loss of the plow soil layer in a period of 67 years.

EFFECTIVE USE OF ORGANIC MATERIALS

The need for more effective use of organic materials from whatever source becomes more evident each succeeding year in soils that have been under intensive cultivation. Frequent cultivation and lack of crops that provide organic residues have resulted in the decline of soil organic matter with consequent deterioration in soil structure and physical properties for efficient plant growth.

From studies of the effect of different mulches on soil properties, the Oregon station found that a straw mulch saved moisture equivalent to 2 or 3 inches of rainfall in dry weather, principally in the upper 2 feet of soil. A trash mulch had a lesser moisture-saving effect. Nitrates were as high under straw mulch after it had been established for 3 years as under clean cultivation, and the soil cultivated or mulched with straw was generally higher in nitrates than the plot scraped to control vegetation. A scraped area became drier than the plots given other treatments. Straw mulch caused a marked increase in soluble potassium but little increase in calcium in the topsoil. Trash mulch increased the soluble potassium to a lesser extent than did the straw. But straw and trash mulches increased the organic matter content of the topsoil and the water-stable aggregates.

From a long-time study in the Palouse area, where the soil has been depleted of organic matter by the practice of growing successive crops of wheat with intervening years of clean fallow, the Idaho station has shown that if the straw is returned to the soil with an additional 30 pounds of nitrogen per acre, organic matter and nitrogen can be maintained in the soil and wheat yields increased 10 bushels per acre at a cost of about \$4.50 per acre. With the fertilizer cost subtracted, the result was a profit of \$8.80 per acre at 1945 prices.

Under Tennessee conditions, organic mulches of wheat straw and sericea lespedeza were compared to determine the effect on applied nitrogen and soil moisture. From applications of 50 pounds of nitrogen per acre, the Tennessee station reported that wheat straw mulch conserved the soil moisture supply and continued to reduce materially the outgo of nitrogen. The sericea hay mulch conserved the moisture supply to a much less extent than the wheat straw mulch, and the outgo of nitrogen was decidedly greater.

As a potentially important source of an organic material having fertilizer value that is currently being wasted to a large extent, the New Jersey and Oregon stations conducted investigations on the fertilizing value of sewage sludge. The New Jersey station reported the sludge not quite as effective as cow manure. When extra potash was applied to the sewage sludge there was very little difference between the cow manure and the sludge. The Oregon station reported the sludge to be especially effective in supplying nitrate nitrogen and to cause about the same increase in growth as good stable manure.

With limited supplies of both chemical fertilizers and organic materials, the stations continued to stress the importance of proper conservation and use of farm manure. For example, the Vermont station determined the nutrient losses from manure spread during the winter and found average nutrient runoff losses from an application of 10 tons of untreated manure to be as follows: Nitrogen, equivalent to from 20 to 70 pounds of sodium nitrate; phosphorus, equivalent to

from 12 to 25 pounds of 20-percent superphosphate; and potassium, equivalent to from 27 to 55 pounds of 50-percent muriate of potash. Rather large amounts of nitrogen may be lost in the runoff when heavy applications of manure are spread on frozen ground. The results thus show that for maximum fertilizer benefit from farm manure the farmer should not apply manure when the soil is frozen.

The importance of conservation of poultry manure for providing needed plant nutrients in poultry-producing areas was again shown by investigations of the Pennsylvania station, indicating that 64 percent of the original nitrogen and 41 percent of the organic matter of old manure are lost as a result of present methods of handling. These losses were very markedly reduced through methods of care, handling, and use developed by the station. The practical importance of poultry manure is illustrated by the fact that the annual production of 1,400,000 tons in Pennsylvania contains 20,780 tons of nitrogen, equivalent to that in 129,875 tons of nitrate of soda or 98,952 tons of sulfate of ammonia. The phosphoric acid produced amounts to 13,478 tons, equivalent to that contained in 67,390 tons of 20-percent superphosphate, and the total potash is equivalent to 6,599 tons, or that contained in 10,998 tons of 60-percent muriate of potash. Based on the present system of management, the poultry manure recoverable from the dropping boards and from floor litter is valued at \$2,339,758, or a recoverable value of \$7.86 per ton.

AGRICULTURAL ENGINEERING

Research pointing the way for the establishment and maintenance of a secure, permanent, and economic agriculture for the general welfare of the country has been the objective of the State agricultural experiment stations since their inception by law in 1887. Agricultural engineering has made contributions to these objectives for farming as a business and a method of livelihood through the application of fundamental engineering principles toward the rational development of land, power, machinery and equipment, structures, and conservation practices.

The items which follow give examples of results of engineering research conducted at State agricultural experiment stations that contribute to the building of a sound agriculture.

LAND DEVELOPMENT

The California, Colorado, Montana, Utah, Arizona, and Arkansas stations, cooperating with the Department, to meet the demand of farmers for tangible forecasts of available water for irrigation of crops have been engaged in a long-time study of the problem. Snow cover and underground storage reservoir surveying methods have been perfected to a point that the amount of seasonal water available for crops in the areas studied can now be predicted with accuracy. The development of irrigation and drainage techniques, new or improved irrigation structures, with water-flow and conveyance studies, have also contributed to the practical adaptation of engineering science to farming.

The Montana station has developed a low-cost, gasoline-motor-driven "Sno-bug" to aid in the collection of data for forecasting.

Arizona's studies on the cost of pumping irrigation water have indicated that costs are almost directly proportional to the total water lift. Average cost per each foot of lift per acre of irrigated cotton was 13 cents.

Investigations at the Colorado station have indicated a saving of 65 to 95 percent of water formerly lost through seepage by use of thin concrete (2 to 3 inches thick), road oil, or bentonite stabilizers for irrigation ditch linings. Two machines, a trimmer and a smoother, for use in the preparation of subgrades to exact shapes were devised and perfected in connection with these studies, as well as a practical inexpensive headgate frame and measuring flume. The latter devices encourage the betterment of delivery of water to the farm by equitably parceling out the common water supply throughout the entire irrigation system so that closer relationship exists between assessment costs paid and returns received from the crop grown.

Long-time investigation of concrete drainage tile strengths and deterioration by the Minnesota station have enabled the development of definite specifications for these materials. Peat and muck land drainage studies through the use of mole drains and the development of experimental machinery for the practical establishment and maintenance of mole drainage are being conducted by Louisiana, Pennsylvania, North Carolina, and South Carolina stations.

Adaptation of standard farm equipment and the devising of special machinery to attack the problem of pasture renovation through removal of woody vegetation has been a special cooperative research undertaking of the Oklahoma station. It has been demonstrated that by combined use of a one-man power-driven circular saw, a standard mowing machine with heavier blades and guards, and a specially devised brush beater unproductive brush-infested pastures can be economically renovated and reseeded into productive levels for livestock farms.

Michigan station workers have perfected an easily portable rubber-tired "reforester" enabling two men to field plant 10,000 conifers in an 8-hour day. The machine will operate on slopes up to 30 percent with a power requirement equivalent to that of a 2-bottom plow. Farm-land areas unsuitable for pastures and cropland may now be converted economically to woodland through the use of this machine.

POWER AND MACHINERY AND EQUIPMENT

The demand for greater production of all farm commodities during the war years, handicapped by a decrease of manpower and the utilization of existing farm equipment, has given impetus to the necessity for devising, improvising, and adapting machines to the problem at hand. Consequently, the stations have been called upon to strengthen their studies on mechanization of all farming operations toward greater efficiency in the use of total power available. Analyses of segmented farm operations, by industrial techniques derived from time-and-motion studies adapted to agriculture, have given information as to where improvements in power use, machines, and procedures could be most effective.

To devise means of utilization of electricity in agriculture has been one of the important activities of the State stations. With electricity brought to 270,000 additional farms during 1945 more than 3,000,000

of the 4,950,000 farms now have this source of power. Active research projects have been pursued in the application of electricity to farming operations through experimentation and development of equipment for preservation of farm products by freezing and cooling; for various heating, lighting, and ventilating adaptations; and for pumping, shredding, grinding, and loading operations. Resulting products from these studies go far to release the operators' time from farm chores for other important activities necessary for the success of the farming enterprise.

Efficiencies of machines in advanced stages of their life have been compared with new equipment performance. Tractor fuel-consumption tests under varying drawbar loads made at the Pennsylvania and Nebraska stations have indicated savings of 1 to 2.5 gallons of fuel per day through simple carburetor adjustments, proper loading, and the use of fuel for which the engines were designed.

The power take-off dynamometer developed by the Ohio station has enabled the analysis of power losses in farm machines. Studies of the recorded data obtained under actual operating conditions have indicated proper adjustment standards affecting over-all power requirements and machine efficiencies. Tillage meters applied to farm implements have also provided basic information for improving design. Resulting new tools wear longer, do better work, pull easier, save tractor fuel, and conserve the operator's time.

A new experimental machine for the control of cover crops by shallow cultivation without the formation of plow sole has been developed by the California station.

The Oregon station has designed, built, and tested 12 improved vacuum harvesters for the filbert nut crop. These machines collect, husk, and clean in one continuous field operation. California almond growers are adapting this machine to their specialized needs. Another achievement in the mechanization of agriculture is the development by the Oregon station of a suction-type clover-seed harvester released to farmers during the year.

Studies of mechanical field loading of sacked potatoes at the North Dakota station have resulted in the development of an experimental one-row field loader powered by a 1.75-horsepower gasoline engine. The loading unit is attached to the truck being loaded by a special hitch arrangement. Savings of the labor of one man are effected through the use of this equipment.

The sugar-beet harvester developed by the California station in 1944 and 1945 has been further improved. Refinements in the operation of topping, top removal, soil and trash removal, and root disposal have been accomplished to a level which will satisfy commercial growers' requirements in any beet-growing area. Resulting from these industries' studies and the development of specialized machinery, the man-hours required for growing sugar beets have now been reduced from 100 to 35 per acre.

To reduce the job of cutting seed potatoes before planting the Colorado station has devised a stationary double-edge cutting knife arranged so as to be covered with a continuous flow of mercuric chloride disinfecting solution to prevent the spread of bacterial ring rot. This new device, easily constructed at little cost, has reduced the time required to do the work by 25 percent with excellent control of the spread of infection.

Progress is being made in the mechanization of sweetpotato production. The new transplanter, vine harvester, and tuber shredder, developed cooperatively by Southern State station workers and the Department, are being field-tested before release for commercial production. It had been previously determined that sweetpotato vine hay and dehydrated sweetpotato culls were excellent sources of feed for animals. These machines will relieve the labor requirements for the production of this crop resulting in the utilization of normally waste residues that are high in feeding values.

A machine and method for treating seed with hot water to destroy seed-borne diseases has been devised by the Idaho station. Commercial seed companies are using the developed machine and method extensively throughout the State.

The Arkansas, Louisiana, North Carolina, South Carolina, and New York (Cornell) stations have been engaged in experimental development and testing of liquid and gas fuel flame cultivators for row crops. Experimental weeding operations have indicated that the propane-butane units are cheaper in first cost and cost of operation. Flame cultivating of corn and cotton killed practically all weeds without injury of the crop when the plants were several inches taller than the weeds. On the other hand, it was difficult if not impossible to kill even small weeds without serious damage to spinach. Results with green beans, soybeans, peas, and cabbage ranged between those obtained with corn and spinach. General observed residual effect from the experimental cultivation tended to uphold the claim that when the first weed crop was killed by flame there were no more weeds for the season, for this type of cultivation does not disturb the soil as does plowing which brings more weed seed into the germination zone. Weeding by flame costs about one-third to one-fifth as much as the hand labor required for hoeing cotton and sugarcane. With further improvements in burner design and operating technique it is expected that additional crops may be successfully and economically flame weeded and thinned.

The several phases involved in the mechanization of the cotton crop have been of major concern in the agricultural experiment stations of the Southern States. The liquid fertilizer placement equipment developed in past years has been further improved. Equipment for planting of fuzzy, fuzzy matted, pelleted, reginned, and acid delinted cotton seed have been or are now in the process of being designed in an effort to obtain ideal plant stands for the adaptation of improved cultural mechanical production of the crop. Plant breeders have been developing new upright cotton strains adapted to the experimental cotton stripper and picker machines. With chemical defoliation also entering the over-all picture, experimental results obtained from the utilization of these new machines and techniques have indicated sharply reduced over-all production costs with a highly satisfactory resulting product.

Experimental studies cooperative with the Department on the preservation of the natural nutritive content of forage crops through artificial drying to safe moisture storage percentages is being actively pursued by a number of State agricultural experiment stations, including Alaska, Idaho, Illinois, Indiana, Iowa, Maine, Minnesota, Missouri, Michigan, New York (Cornell), New Hampshire, North Carolina, Pennsylvania, Texas, Tennessee, Vermont, Washington,

Wisconsin, and Virginia. The development of methods and machinery to successfully solve this important problem for agriculture holds a prominent place in research programs. Ventilation of the crops by blowers connected with tunnels and laterals installed in barn mows and specially built structures, with and without external heat, have given preliminary results indicating that such systems may have great possibilities in that the plant leaves are saved, over-all operations are speeded up, and much of the uncertainty in hay making due to "weather factor" is removed. Economic studies of hay-making field methods and the adaptation of newly developed machinery to harvesting, transporting, and storage of the crop are also being considered. Experimentation is cooperative between the agricultural engineers, agronomists, chemists, economists, and animal husbandry-men, thereby drawing together all phases of the problem into coordinated effort.

STRUCTURES AND STRUCTURAL EQUIPMENT

The development of structures of maximum utility and flexibility, efficiency, and durability, which will show a reasonable return on the investment over an appreciable period of time, has been a concern of the stations. Representative studies of the problem, in which the needs of both the large farming enterprises and the small family-size units have been considered, are cited in the following discussions.

The Nebraska station has developed methods of constructing and operating an automatically cooled "shell" bin storage system for potatoes which prolongs their storage life and decreases shrinkage and sprouting losses. In addition, a precooled type of deep-pit storage has proved so efficient and inexpensive that extensive adoption on farms of small growers is forecast. Data obtained from observations at the Colorado station of experimental storage of potatoes have confirmed the findings of the Nebraska station and have indicated added profits up to 6 cents per hundredweight because of improved market quality.

Studies on harvesting and storage of onions at the Utah station showed that topping the crop before pulling gave as good keeping results as if the onions were pulled and then topped. Further, this method reduced hand labor involved, in that the onions could be lifted from the ground by a plow and when packed loosely in slatted crates, so that they could be ventilated by forced circulation, spoilage was materially reduced.

The New Jersey station field experiments, based on new ideas in poultry housing construction, using a wood framework overlaid with asbestos board have indicated that a structure produced by this method is economical, neat and attractive, easily erected through the use of prefabricated sections, has considerable insulating value, and needs no painting upkeep. For more permanent construction, additional studies have been made on the use of masonry for poultry housing through the use of cinder block for walls and cement for floors with a shed-type roof. Test results of this structure gave assurance that correctly designed masonry construction will give highly satisfactory performance.

Research to develop designs for convertible farm buildings has been in progress at the Iowa station for several years. Because of the fact

that the general-purpose barn must house a number of enterprises under one roof, its functional requirements vary from season to season and also change with the type of farming operations. By using a "modular," "unit space" method to arrive at a flexible functional structure, a building has been devised whereby all interior partitions are movable to positions desired for specific farm operations. This type of structure more nearly fits the farmer's conception of an all-purpose barn adaptable to his individual needs and operations.

Cooperative grain drying and storage studies have been continued. Experiments on corn drying at the Iowa and Nebraska stations using forced ventilation with supplemental heat have shown that ear corn of 26 percent average moisture, when cribbed, could be dried in about 2 weeks to an average moisture content of 16.37 percent by the systems developed. Drying temperatures from 190° to 200° F. caused no visible damage to ear corn but upon shelling the germ ends were shriveled, somewhat brittle, and discolored. The carotene and amide nitrogen content were not significantly different from that of the room temperature air-dried checks.

The Texas and Arkansas stations have developed experimental driers for handling of combined grains. Indications are that this equipment can be used successfully in drying of oats, wheat, and barley and with minor changes clover, grass seeds, and peanuts. Estimated cost of a unit capable of handling grains as harvested by small combines is 600 to 700 dollars with its operating cost not exceeding 30 cents per ton when the moisture content of grains is to be reduced from 20 to 13 percent using fuel oil as a source of external heat.

Experimental development and testing of new structures and equipment for the curing of tobacco conducted by the North Carolina, Virginia, and Kentucky stations in cooperation with Department, have given an excellent product with a reduction in over-all production costs. Oil and coal stokers with automatic control equipment installed complete in these barns for \$250 to \$350 have enabled the curing of 500 pounds of tobacco for \$3.50 to \$8.50, respectively, as against \$18 to \$24 by the older methods.

Results of preliminary studies made at the Iowa and Pennsylvania stations adapting steel and laminated wood structural members to farm building construction have indicated sizable reductions in over-all investment costs. Further investigations of prefabrication techniques as well as the accumulation of additional information on the functional requirements of farm structures, based on an analysis of the fundamental requirements of farm animals for maximum production levels, are necessary before satisfactory designs for farm buildings can be worked out to effect appreciable construction savings. Cooperative research between the Department and the stations is now being set up to acquire the missing data through the use of planned and existing special experimental laboratory facilities.

RESEARCH ON PLANT DISEASES

Steady progress during the year was reported by experiment stations in all parts of the country in their continuing program of research on plant diseases and their control. Much of this research was conducted cooperatively between stations on a regional or on a national basis, often with aid from the Department. The results

of such scientific teamwork have done much to expedite the solution of problems faced by American agriculture and to prevent premature adoption by farmers in general of new practices that have but limited or local application.

The examples given here of the results of experiment station work on crop disease problems, reported mainly during the fiscal year 1946, provide a partial picture of the scope of the research.

NEW FUNGICIDES

American agriculture is definitely entering a new era in crop protection. Research has disclosed an unbelievable rich mine of plant protective materials in the enormous range of organic compounds which the chemical industry is now able to synthesize. Nation-wide experiment station trials of the potentially more useful, among the thousands of substances put through screening tests, have shown the superiority of a number of these over the familiar inorganic sulfur and copper sprays and dusts on which the farmer and fruit grower has hitherto had to depend for defense against the innumerable infectious diseases which attack his crops. Several have already been adopted widely in practice, and more will follow as thorough trials prove their merit for different purposes.

In the following reports of progress in plant disease control investigations repeated reference is made to newer fungicides. These are designated mainly by code numbers or trade names since the descriptive chemical appellation is invariably long and cumbersome and chemists have not yet conferred short, specific common names on most of them.

TRUCK-CROP DISEASES

Bean diseases assail the truck crop grower. In Ohio station tests on the control of pod infections of anthracnose, with bordeaux as the standard, Zerlate (2-100) consistently surpassed all other materials. Fermate, Dithane-zinc-lime, nickel ethylene bis-dithiocarbamate and bordeaux were reasonably effective but not equal to Zerlate. Isothan (1-100) was comparatively ineffective.

Florida Belle and Florida Wax beans, originating from crosses made by the Department and finally selected at the Florida Everglades station, were released recently. These are productive, attractive, and resistant to powdery mildew, rust, mosaic, heat, and drought.

Cabbage disease problems are persistent but the Massachusetts station found that the soil-borne cabbage club root disease could be reduced successfully by applying to the soil pyridylmercurichloride or ethyl mercury phosphate mixed with lime. The results were better than from using lime alone, while lime alone proved better than mercury salts used without lime.

The Wisconsin station has also developed new cabbage breeding material which, through crossing, promises to combine resistance to fusarium yellows with resistance to mosaic and high vitamin C content and, through a kale-cabbage cross, with resistance to club root.

Cantaloup and cucumber diseases continue to spread. One answer to this problem lies in resistant varieties. Considerable resistance to both fusarium wilt and macrosporium leaf spot has been found and apparently fixed in hybrids of the Honey Rock and Hearts of Gold

types of muskmelons developed in the Michigan station breeding program.

The Delaware station conducted field trials of dusting for the control of downy mildew of cucumbers and cantaloups. By the end of July untreated fields were practically dead while cucumber foliage persisted in blocks treated with four applications of copper oxychloride or yellow cuprous oxide, and melons of high quality were produced where sprays or dusts of fixed copper were used.

In Florida station tests with cucumbers, Spergon, Fermate, and Dithane have not been surpassed by standard copper sprays against downy mildew. Several other new organics, not yet on the market, appeared promising but it will take several more seasons for proper evaluation. At the Louisiana station Fermate dust completely protected cucumber plants from both downy mildew and anthracnose in severe epidemic form. The former standard bordeaux spray caused much injury as did Cuprocide. Yields with 10 percent Fermate were 461 bushels per acre, practically double the bordeaux yield. Dithane spray appeared more promising than the copper dusts but not equal to Fermate dust.

Celery blights succumb to newer fungicides. The Ohio station obtained best cercospora blight control in 1945 with Zerlate. Dithane-zinc sulfate-lime gave next best results. The Connecticut State station found the latter effective, with bordeaux next best but causing injury. A new material known as G4, developed as a mildew-proofer for fabrics, showed promise for cercospora control.

Lettuce seedlings are often attacked by damping-off. Highly successful control was secured in tests by the North Carolina station by applying less than $\frac{1}{4}$ pound of Fermate or Tersan (Thiosan) per 100 square yards of plant bed in a drench as soon as the plants came up and every 10 days or 2 weeks afterward. Grower adoption of this method is thought to have prevented a serious shortage of plants for setting the 1946 lettuce crop in North Carolina. Preliminary tests indicated that the practice is applicable to other crops like pepper, eggplant, tomato, and tobacco.

Hawaii station scientists have found a serious leaf disease of lettuce in the Islands due to a species of *Stemphylium* apparently new to science. In spraying tests for septoria and stemphylium leaf spots in Hawaii, yield increases were obtained with Tribasic copper sulfate, Fermate, Zerlate, Phygon, and Dithane-zinc sulfate-lime.

Onion diseases resulting from soil-infesting fungi hamper production in many areas. The New Mexico station tried out two soil fumigants against the soil-borne pink root disease of onions. Chloropicrin decidedly reduced the disease but was too costly. DD mixture was apparently not effective. False blight of onion was found to be one of the effects of pink root. Some apparently pink root resistant lines of onions showed promise. Yields of onions grown from seed in pink root rot infested soil at the Massachusetts station were increased nearly 49 percent by treating the soil with Tersan (70 pounds per acre) and about 37 percent with Fermate. A zinc salt of 2,4,5-trichlorophenol applied in fertilizer gave increase in stands and growth of onion seedlings. Fermate is now being mixed with fertilizer for sale by at least one manufacturer.

Based on the results of Indiana station experiments showing the benefits of treating onion seed for smut control with Arasan, enough was sold to treat 29,000 pounds of seed. All growers used it. In New York State, in line with the findings of the Cornell station, growers used more than 20,000 pounds of Tersan for this purpose.

Spinach blight, due to the cucumber mosaic virus, is extremely destructive in some areas. The Arkansas station proved that Old Dominion and Virginia Savoy spinach varieties are the only common varieties of spinach resistant to severe damage from the blight. Commercial control is now achieved by the use of these varieties. One grower estimated a gain of \$33,000 on one crop by following the lead of the station and using a resistant variety.

Tomato breeding for disease resistance is moving forward rapidly to solve for growers some of their most perplexing disease problems. The Hawaii station reports good prospects for combining, in single fixed lines, resistance to fusarium wilt, gray leaf spot, and the spotted wilt virus, and progress is being made toward including high vitamin C content and resistance to root-knot nematode. Hybrids between nematode-resistant Peruvian tomato and common tomato, obtained by embryo culture, carry nematode resistance.

The wild Peruvian tomato with tiny fruits like green peas carries resistance to fusarium wilt as well as to root knot eelworm. The Georgia station tested 37 hybrid strains obtained by crossing this wild type with common tomato varieties. Several strains appeared almost immune to wilt and few highly resistant to root knot.

New tomato lines of the Indiana station draw fusarium resistance from the wild cherry tomato (*Lycopersicon pimpinellifolium*) crossed with Indiana Baltimore and Rutgers. From the hairy wild tomato (*L. hirsutum*) crossed with the cultivated tomato was derived progeny showing resistance to *Septoria* and almost approaching commercial quality.

The Ohio station reported progress in its program of breeding tomatoes for resistance to the common race 1 of fusarium wilt and for resistance to the new race 2 recently isolated in Ohio. Wilt-resistant canning types under test in 1945 again outyielded the standard Indiana Baltimore and Rutgers, but a wet year is needed for final conclusions on their merit. Glasshouse types selected for resistance to wilt equaled or surpassed the standard Globe variety.

Verticillium wilt attacks nearly every acre of tomatoes in Utah each year. In 1945, the disease was unusually destructive, the loss averaging nearly 40 percent for 118 fields in five counties. The Utah station, testing 17 different tomato species and varieties and 60 hybrid selections, found highest resistance in Peruvian wild tomato and its hybrids with common tomato none of which are yet acceptable commercially. All commercial varieties common in Utah proved susceptible. Pan America, practically immune to fusarium wilt, was highly susceptible to verticillium wilt.

The Mississippi station tested 42 lines of tomatoes involving four different species. Only *Lycopersicon pimpinellifolium* and *L. hirsutum* contributed tolerance to southern ashy stem blight (*Sclerotium rolfsii*) to their hybrid offspring with the edible tomato (*L. esculentum*). The highest degree of tolerance was found in VBL 42-23. Four other lines were highly tolerant. A high degree of promise was shown in

a Mississippi (Delta) station strain of Pan America and in strains from the Regional Vegetable Breeding Laboratory at Charleston, S. C.

A severe general attack of tomato mosaic in 1945 revealed the existence of mosaic-resistant strains of tomato in the breeding plots of the Nebraska station. Among them were the Pearl Harbor tomato, developed by the Hawaii station, and several Nebraska crosses.

Fungicides for tomatoes have occupied the attention of many experiment stations, a number of which have conducted cooperative experiments and pooled their results. In 1944 and 1945, experiments by the Delaware station showed that of six different spray treatments for tomatoes the one that resulted in the least disease in both years was Zerlate (2-100). Yields in 1945 were highest for Zerlate. The next highest came from plots sprayed alternately with Fermate and Tribasic copper sulfate. Bordeaux and Copper Compound A gave definite protection, but Zerlate gave much better protection against the anthracnose spots on the fruit.

The Indiana station learned by 15 tests at 10 locations that if the first application of spray is delayed until the leaf diseases appear or until midsummer weather is favorable for their widespread development, economic returns could be expected. The average gains from such delayed spraying with bordeaux 8-4-100 amounted to about 1½ tons per acre, usually with improved quality. Alternaria and septoria blights were accompanied in places by severe phytophthora late blight. All were held in check.

The Michigan station found that Fermate, while rather effective against anthracnose on tomato fruit, did not give adequate results on leaf diseases. In one test Zerlate appeared more efficient against both types than Fermate.

In an 11-State cooperative experiment in 1944 (Maryland, New Jersey, Delaware, Connecticut, Pennsylvania, Indiana, New York, Ohio, Illinois, South Dakota, and Michigan) alternating sprays of Fermate and Tribasic copper sulfate in general gave the best control of tomato diseases. In 1945 the cooperative trials were continued and the average results of 13 experiments gave top salable yields (11.28 tons per acre) to the Fermate-Tribasic alternating schedule, with Zerlate next (10.92 tons) and then Fermate (10.45 tons). The checks yielded an average of 9.28 tons.

In New Hampshire station experiments, Zerlate, Puratized, and Phygon gave increased yields of tomatoes in the order named, although none of the 10 materials tested prevented eventual complete defoliation by early blight. Dithane was best for disease control but was injurious to tomato foliage. Bordeaux mixture and copper oxychloride sulfate stunted the plants.

Yields of tomatoes were increased 33 to 68 percent by spray protection in experiments by the Texas station. Copper Compound A, Tribasic copper sulfate, Dithane-zinc-lime, and Spray Cop were compared with standard bordeaux. Spray Cop was superior with 270 bushels per acre for the tomatoes that got only insecticides. Bordeaux was inferior to all the other copper sprays.

The Virginia station found Phygon to give excellent control of late blight on tomato but it was not as effective as the copper fungicides against early blight and septoria leaf spot. In general, applications

of cuprous oxide and Tribasic copper sulfate resulted in greatly increased yields of marketable fruit. The average increase of cuprous oxide over 6 years was 172 bushels per acre.

The Colorado station reports successful results in reducing tomato fruit rot caused by *Phytophthora capsici* by the use of copper dusts and sprays of copper oxychloride, Yellow Cuprocide, and bordeaux. Results from tests with the use of copper sulfate in sprinkler irrigation water for reducing field spread of fruit rot were promising. Breeding for resistance showed some promise too.

In New York State station tests Phygon, Fermate, Thiosan, and Dithane sprays were too injurious to tomato seedlings although most of them controlled damping-off without injury where used to drench the soil, not the leaves.

Tomato-seed treatment has been improved. At the New Jersey station some 37 materials were tested. Machine-application of New Improved Ceresan dust gave good seed protection and as much seed could be treated in an hour as in a day by the old method. In 1945 nearly 20,000 pounds of New Jersey certified tomato seed were machine-dusted.

The New York State station again found that results of treating tomato seed with the organic fungicides Arasan, Fermate, and Zerlate were better than the results with copper materials. Standard New Improved Ceresan considerably delayed emergence. The organics did not.

Watermelon fusarium wilt often causes a total loss of crop in heavily infested soil. Losses in stand of from 20 to 50 percent are not uncommon. A Florida station scientist began selection and breeding of watermelon for wilt resistance in 1930. In 1935 he had produced the Leesburg melon, 75 percent resistant or better, which permitted reutilization of thousands of acres of land which were absolutely unsafe for usual varieties. In 1941 the superior, wilt-resistant Blacklee melon was produced. Florida growers are planting it with great success. One million dollars is a conservative estimate of the value of these two varieties to Florida growers in 1944.

High resistance to fusarium wilt, high quality, and medium size is shown by the new watermelon, to be named "Dr. Miles," developed jointly by the Tennessee and Mississippi stations.

FRUIT AND NUT DISEASES

Apple scab costs the American fruit grower more to fight than any other single apple disease. Lime-sulfur, recognized for years as the most effective scab spray material, often seriously injures the fruit and the productive capacity of the tree.

In experiments with 18 materials, the Rhode Island station found both Puratized (1 pint of 5 percent in 100 gallons) and Phygon (1½ pound to 100 gallons) to be outstanding, killing out the apple scab fungus from incipient infections. The Virginia station states that the exceptional effectiveness of Puratized may be reduced by certain hard waters or by lime. Its mercury content argues against its use in fruit cover sprays.

Poor scab control resulted in Rhode Island with wettable sulfur, Zerlate, and Dithane. The inability of Isothan Q15 to build and retain a protective coating was corrected by use of a factice or a celite as a

deposit builder. The Maine station found Puratized N5E at the weak dilution of $\frac{1}{2}$ pint to 100 gallons less effective than wettable sulfur in a bad scab year, while Dithane-zinc-lime was nearly as effective. In these trials dry lime-sulfur surpassed the other materials compared. On McIntosh at this station Isothan Q15 gave little control of scab but caused premature drop of half the leaves and all the fruits.

On McIntosh at Waltham, the Massachusetts station found Isothan Q15 ($\frac{2}{3}$ pint to 100 gallons) ineffective in killing scab spores or eradicating scab spots, but Puratized ($6\frac{1}{3}$ ounces to 100 gallons) was effective in both respects. Fermate killed the spores but not the spots. Lime-sulfur burned. Foliage sprayed with Puratized looked best.

The Virginia station found that although Isothan Q15 has shown promise as a scab eradicant when used at the right time, lime and lead arsenate appear to seriously reduce its effectiveness. Methasan and Zerlate appeared to show some promise on apples and Compound CC341 approached lime-sulfur in effectiveness against apple scab, but was not promising against cedar-apple rust.

In experiments by the Ohio station Fermate, Zerlate, Phygon, Puratized N5E, and Guantal gave excellent control of apple diseases and caused less injury than lime-sulfur or copper combinations. Puratized did not give good apple scab control at the weak dilution recommended but controlled well when 10 percent material was used at 1 pint to 100 gallons. Fermate and Zerlate were compatible with arsenate-of-lead-oil spray. The West Virginia station demonstrated the compatibility of Fermate, Isothan Q15, Phygon, and Puratized with both DDT and lead arsenate when used on apple foliage.

The Illinois station found the most efficient of the materials tested for apple scab control to be Puratized, copper 8-quinolinol, and Fermate, in that order. They did not injure. 8-Quinolinol and Isothan 15 and 32 were less effective. The Missouri station found that Fermate and Methasan sprays controlled apple scab as well as the standard sulfur program and gave excellent control of cedar-apple rust. Dithane-zinc-lime was less effective.

Bitter rot on Golden Delicious apples was controlled by Fermate, Methasan, Puratized N5E, Guantal, and Phygon in Ohio station tests. Bordeaux gave control but injured fruit and foliage. Through use of these new materials it will now be possible to raise apples profitably in the bitter rot area of southern Ohio. In Arkansas, in cooperative work with the Department, Phygon (1-100) proved to be the most effective material employed for the control of bitter rot. Dithane with zinc and lime gave very little protection. Fermate was not as good as Phygon but much better than bordeaux-oil and caused no injury. Phygon did not injure leaves but caused surface spotting of the fruit. The Virginia station reports that Phygon cannot be used safely with summer oil.

Apple blotch was controlled equally well in Illinois station tests by Fermate and copper 8-quinolinol; not as well by Puratized at the strength used. At the Missouri station Fermate equaled bordeaux against blotch and caused no injury while bordeaux severely damaged leaves and fruit.

Cherry leaf spot struck many eastern orchards a heavy blow in 1945. Unsprayed trees in some areas dropped all their leaves and died during the following winter. In West Virginia experiments

lime-sulfur failed to give appreciable control that year and much die-back resulted, while trees sprayed with bordeaux or fixed coppers suffered no die-back and bore well the next year. In tests by the Virginia station cooperating with the Pennsylvania station, Compound CC341 again surpassed all other materials, including bordeaux, for leaf-spot control. Dithane was least effective. Application of station findings by growers in this sour cherry area added an estimated 12 percent to the 1945 crop, which increase in two counties alone totaled about 3,000 tons.

In Missouri station experiments Fermate did not control cherry leaf spot as well as bordeaux although not causing injury like the latter. Methasan was outstanding, producing almost as good control as bordeaux but without such injury. Puratized was better than Fermate; Dithane not so good. The Wisconsin station got best leaf spot control but smallest cherries with bordeaux. Tennessee Copper, Compound CC341, and Fermate, all with lime, gave good control and also good fruit size.

Brown rot control was effective when Minnesota station scientists applied Fermate (1-100) to Sapa cherry-plum hybrid 10 days before harvest. It also markedly reduced fruit rot in storage to less than 3 percent after 1 week. Wettable sulfur-Tribasic copper sulfate (3-1-100) gave almost as good control in the field and fair in storage. Wettable sulfur, the normal standard, was not equal in the field and 13 percent storage loss resulted.

Western X-disease due to a virus present in wild chokecherry in Utah was found by the Utah station, in work cooperative with the Department, to be capable of producing a wilt and decline type of malady on sweet and sour cherries on mahaleb rootstock as well as causing disease on peach.

Other virus diseases of cherry are of growing concern. A Department scientist cooperating with the California station found that the ring-spot virus may be carried to a limited extent in seeds of Mazzard cherries used as understocks for sweet and sour cherries, disclosing a hitherto unknown means of spread against which precautions can now be taken. The Oregon station reported the discovery of two new cherry viruses, provisionally called Lambert mottle and Weber disease. The former has killed sweet cherry trees within 2 years from inoculation. The latter can apparently cause trees to go wholly or partially out of production the next season after apparent health.

Citrus psorosis, virus-caused scaly bark, is being treated extensively in California by the chemically induced bark-scaling method, developed by the Citrus station. The dinitro compound DN75 is used instead of the standard bark-scraping method at great saving in cost.

"Stubborn" disease of citrus, which cripples navel orange trees and causes misshapen, bad-tasting fruit, was first reported by the California Citrus station in 1944. The station proved its virus nature.

Currant leaf spot and anthracnose can be controlled effectively by Fermate (2-100) or Tennessee 26 copper (3-100). Copper Compound A (4-100) proved less effective in Minnesota station experiments.

Black rot of grapes was controlled by Fermate about as well as by bordeaux in Missouri station plots. The New York State station found

nothing superior to bordeaux with rosin fish-oil soap in 5 years of experiments for the combined control of black rot, downy mildew, and powdery mildew on American grapes. Although Yellow Cuproside was better than six other fixed copper materials, it did not surpass bordeaux. Fermate was better than bordeaux against black rot but not against downy mildew. It did not control powdery mildew. Phygon controlled downy mildew better than bordeaux and controlled black rot as well as bordeaux. At 1-100 and sometimes at 0.5-100 it caused some injury to the grapes. The variety Clinton appeared resistant to all three diseases. Concord was free from downy mildew.

Grape viruses are serious threats to the industry. The California station found evidence that a new disease killing European-type grapes in one locality is due to a mosaic virus which may have come from Europe. The difficulty of eradicating the destructive virus of Pierce's disease of grapes from the country is emphasized by the research of this station showing that the virus may attack at least 64 species of plants belonging to 16 families, including alfalfa, and also 84 kinds of grass common in vineyards.

Papaya virus studies at the Puerto Rico University station have brought conclusive evidence that papaya mosaic is transmitted by at least three species of aphids. Bunchy top, on the other hand, is transmitted by a leafhopper. Guided by this knowledge, research on control is being carried out to bring back the papaya industry, now virtually destroyed by these diseases. The new ring-spot disease of papaya, discovered in an area near Honolulu where there is a concentration of papaya culture, appeared to be spreading rapidly. It stunts growth and reduces fruit number and quality. The Hawaii station found it to be an insect-carried virus disease. Intensive research was being directed toward eradication and control.

Powdery mildew of papaya, the Hawaii station showed, can be controlled most effectively by wettable sulfur, Yellow Cuproside, and Tribasic copper sulfate. Control was satisfactory, however, with Zerlate, Isothan Q15, Puratized N5E, and Phygon. Damping-off of papaya seedlings was well prevented by Phygon, Dow 9B, and Spergon.

Bacterial spot of peach, another cause of loss in many areas, has proved difficult to control with older materials. The Illinois station, however, reports that either Fermate or copper 8-quinolinol, at $\frac{1}{4}$ pound to 100 gallons, definitely prevented infections on the fruit and caused no foliage injury although not preventing foliage infection. Severe drop of leaves was induced by Isothan Q15 and 32, 8-quinolinol, Phygon, Hyamine, Dithane, and Puratized. The Ohio station did not get control in testing the last at very weak dilution.

Pecan root rot due to the soil-borne fungus, *Phymatotrichum*, works destructively in some Arizona groves. The Arizona station has found that giant panic grass grown in the orchard for four seasons has apparently checked any advance of the fungus from diseased to healthy trees.

Pear scab attacks Comice pears, famed for superior dessert quality. Yet the skin is so sensitive that ordinary fungicides often cause a russeting objectionable in the luxury gift packages which provide their most profitable outlet. Experiment station work in southern Oregon proved that Fermate controls scab and practically eliminates russet-

ing. Most of the 2,000 acres of Comice pears in that area were therefore sprayed with Fermate in 1946. In the Hood River Valley of Oregon, Federal-State cooperative research led to the spraying of all Anjou pears with Fermate instead of wettable sulfur with the added value of the resulting marketable crop reaching perhaps \$800,000. Increase from the usual average of 200 boxes per acre to 300 boxes in 1946 is attributed in large measure to this change.

Raspberry anthracnose and septoria spot are widely troublesome. Ohio station tests indicated that the standard lime-sulfur spray controlled the former better than Fermate, Zerlate, Elgetol, or Puratized N5E. *Septoria* was controlled best by Fermate in Tennessee station experiments. Red raspberries sprayed with this material outyielded the next best plots sprayed with Tennessee 26 fixed copper spray by over 12 percent.

Stone-fruit viruses are often difficult or impossible to detect in nursery stock or in trees from which nurserymen obtain propagating material. The Oregon station, however, has developed a simple scientific method whereby Shirofugen or Kwanzan flowering cherries, through a budding procedure, can be used to disclose the presence of virus in trees under test. This method is being recommended for practical application.

Strawberry root rots seriously damage crops in many areas. A black root-rot tolerant strawberry variety, P136, developed at the Tennessee station yielded 60 percent more in tests at Springfield, than Blakemore, the next highest yielding variety.

Walnut leaf scorch was found by the Oregon station and Department in cooperation to be the result of boron deficiency. As a consequence growers in that State have treated about 3,500 acres of Persian (English) walnuts, using about 4 pounds of borax per tree, with returns as high as \$1 for every cent spent for borax. Filberts, however, showed no benefit from borax but responded to nitrogen fertilizer.

FIELD-CROP DISEASES

Bean mosaic and curly top are destructive virus diseases with which western stations have been concerned. The Idaho station has released a new strain of Pinto bean resistant to both diseases. Montana No. 1 strain of Great Northern bean, released by the Montana station in 1943 and growing in popularity, is resistant to common bean mosaic, but another virus, present in some Montana areas in sweetclover, was discovered attacking this new variety. The station is therefore now attempting to develop an equally good variety that will be resistant to both viruses.

Corn root, stalk, and ear rots have, according to a recent study, caused greater total crop loss in the past than any other plant disease complex occurring on any crop in this country, as high as 135 million dollars in an average year. The Illinois station has been testing hybrid lines of corn for resistance to the organisms producing these losses. The result has been greater use by growers of resistant hybrids and definite reduction in the extent of losses from such fungi as *Diplodia*, *Nigrospora*, and *Fusarium*. In a test of 18 hybrid lines in 1945, the Illinois white hybrids, 2184, 2019B, and 2059, along with Illinois 960 and U. S. 35 surpassed all others for low damage to kernel rot.

The South Carolina station found that in that area attention must be directed at stalk borers and earworms which were found to contribute to a most important extent to the invasion of corn by stalk and ear rot fungi.

Corn seed treatment is fully justified by results of continued experiments with newer materials. The Arkansas station got hybrid corn yield increases of 6 to 10 bushels per acre by the use of Arasan or Spergon which were on the whole superior to Dow 9A or B, Yellow Cuprocide, Phygon, Barbak C, or Semesan Jr. The Iowa station found Semesan Jr., Arasan, and Spergon to have a wider range of safety than Barbak C or D and to lose none of their effectiveness when combined with DDT to protect stored seedcorn against insect attack. Using Arasan, the Illinois station got yield increases, with 18 hybrid lines, ranging in 1945 from 1.7 to 24 bushels per acre, averaging nearly 9 bushels.

Corn smut resistance was shown by 25 out of 125 strains of Guatemalan corn tested by the Iowa station in its search for new parental lines to use in its corn improvement program. A special cooperative experiment station has been set up in Guatemala to aid in this program.

Cotton boll rots caused by a variety of fungi gain entrance largely through bacterial blight infections under Oklahoma conditions according to investigations by the State station. Practically complete elimination of seed-borne blight bacteria was accomplished either by sulfuric acid delinting or by dusting cotton seed with Ceresan, New Improved Ceresan, DuBay 1452 F, or Dow 9.

Verticillium wilt of cotton is rapidly becoming one of the most serious problems confronting the growers in southern New Mexico. In that State the station has met this threat by the development and release of a new variety called Wilt Resistant Acala. Seed was being increased in 1946 for distribution to growers whose land is contaminated with the casual fungus.

Phymatotrichum root rot, most damaging of all cotton diseases, can be rendered less destructive by applying manure or manure and sulfur to land planted with early cotton as shown by experiments of the Arizona station. Still better appeared to be the results when early cotton was planted where guar or early sourclover had just previously been grown as green manure crops.

Cottonseed treatment has been improved by the use of new products tested out cooperatively by a number of stations. Among the results recently reported is evidence of the merits of Dow 9 which is apparently nontoxic to man and livestock in contrast to standard mercurials. In Oklahoma station tests this material gave as good increase in stands as New Improved Ceresan or DuBay 1452 F. When used in large amounts for pelleting seed these materials caused bad seed injury but apparently not at normal rates. The South Carolina station found Dow 9 to be as effective against the seed-borne anthracnose fungus as standard mercurials with the advantage that surplus seed treated with it may perhaps be used safely for oil extraction or feeding to animals. The North Carolina station found Dow 9 outstanding in giving high seedling stands and preliminary tests pointed to the excellence of a still newer material GCC 668. It is reported that farmers in that State in 1945 planted 400,000 acres with

cottonseed treated with station-proved materials at an average gain of 125 pounds of seed cotton per acre over untreated seed.

Flaxseed treatment pays, according to Iowa station findings, at least with ordinary machine-threshed seed. Stands were increased about 29 percent while the yields were generally increased somewhat. Arasan and Spergon showed high effectiveness and a wide margin of safety, and the adding of the insecticide DDT did not reduce their effectiveness.

Helminthosporium blight of oats, first discovered in 1944, has already demonstrated its destructiveness. In southern Iowa, some fields were a total loss while many suffered 50 percent loss. In north-eastern New York State it caused yields to fall as low as 5 and 10 bushels per acre in fields of the new Vicland oats which was rapidly winning favor in that area, as elsewhere, because of its rust and smut resistance. The New York State station examined seed stocks of this variety from many States. All carried the fungus in from 1 to 30 percent of the seeds. Fortunately, older New York (Cornell) station varieties, Cornelian, Ithacan, and Lenroc showed no evidence of attack where Vicland nearby showed 32 percent blighted and 18 percent dead plants. The outstanding new Clinton variety as well as Marion and Benton were also found to be resistant. Furthermore, tests by the New York, Iowa, and Arkansas stations showed that seed treatment with certain volatile mercurial dusts provides some measure of helminthosporium control, though not complete. The Iowa station reported that they gave an increase in yield of Overland oats of 19 bushels per acre. Nonvolatile chemicals were of little value.

Oat stem rust is not a serious problem in many areas but the Minnesota station cooperating with the Department has found race 8 of this rust increasing in intensity and extending its distribution recently. This is particularly disturbing since Vicland, Tama, Boone, and other outstanding new varieties of Richland parentage, even though resistant to smuts, crown rust, and other stem rust races, are susceptible to race 8. Plant breeders are now working at high speed to produce varieties as good as these and at the same time resistant to race 8.

Peanut dusting, based on experiment station work, is bringing increased peanut yields in many States, thanks to effective extension service work. In 1945, in Virginia 126 power dusters, 41 of them new, dusted some 20,000 acres for 13 cooperative groups and 5 custom outfits. In North Carolina some 45,000 acres were dusted, probably adding 1 to 2 million dollars to the crop. In Arkansas also the station found that sulfur dust would practically eliminate the almost complete loss of leaves caused by cercospora leaf spot, increasing hay yields almost 50 percent.

Concealed damage in peanuts is the name given to decay of the seeds that cannot be detected without shelling and splitting the seeds. The Alabama station estimates that losses caused in that State approach a million dollars a year, losses to individual growers reaching as high as \$30 per ton. The cause has been unknown. Work by the Alabama station indicated that the fungus *Diplodia* may be mainly responsible for the trouble in the southeastern part of the State and that curing in windrows for 48 hours before stacking prevents most of the damage that usually develops in the stack or shock under slow curing conditions. A study by the South Carolina station revealed

mainly species of *Alternaria* and *Fusarium* in peanuts decayed in the shell. The Florida station has made an important contribution to the solution of the problem, however, in developing the newly released Dixie Runner peanut which is reported to be practically free from concealed damage as well as being productive and high in oil content.

Peanut seed treatment, developed by experiment station research, has been promoted by Extension workers until in 1945 the benefits were extended to about 84 percent of the Virginia peanut acreage and to 125,000 acres in North Carolina, or over three times the acreage planted to treated seed 2 years before. Phygon and Dow 9, added by the Virginia station to earlier tested chemicals, were found highly effective for peanut treatment while Fermate was definitely inferior, being surpassed not only by those mentioned but also by Ceresan, Yellow Cuprocide, Arasan, and Spergon. Effective treatment makes possible the safe use of machine-treated seed at a saving in cost of \$1.25 or more per bag at 1945 labor rates. This gain is in addition to the gain from better stands. The Louisiana station likewise found Fermate inferior. Here Dow 9 almost equaled Ceresan. Arasan was not quite as effective and Spergon even less.

Potato late blight outbreaks, so often of widespread destructiveness, will be met more effectively in future as the result of persistent scientific work on new protectants and the breeding of blight-resistant varieties. The Hawaii station reports the 2-year performance of a new Department seedling, B70-5, to be outstanding in a comparison of some 30 potato strains because of its excellent late blight resistance good yield, and attractive tubers.

In New Jersey station tests, 40 more bushels per acre were produced in plots sprayed with Dithane-zinc sulfate-lime than where bordeaux was used although the former did not control late blight so well. Microgel also made a good showing, better than another basic copper sulfate or basic copper arsenate. Microgel was also compatible with DDT. Plots dusted with it produced more potatoes than those dusted with copper-lime-DDT.

In experiments on Long Island, the New York (Cornell) station did not get as good late blight control or yields with Dithane-zinc sulfate-lime as with Tribasic copper sulfate, COCS, or bordeaux. The new plurimetalllic chromate sprays CC169 and 298 appeared highly promising in preliminary trials.

Of 13 organic materials tested by the Rhode Island station in 1945, only Phygon surpassed bordeaux for late-blight control on potatoes but yields were greatest from plots sprayed with bordeaux mixture.

Potato spray rings are being organized by extension services to put into most effective use, at lowest cost, the best spraying practices worked out by the experiment stations. In New York State 83 custom spray rings, organized for small growers, in 1945 covered over 21,000 acres. In Pennsylvania 101 spray rings covered 17,372 acres for 2,124 potato growers. Production was increased over 21/3 million bushels in the latter State, adding some \$4,000,000 to the farmers' income.

Early blight of potato, an important cause of low yields in some areas, was severe in Delaware in 1945. Experimental plots of the State station, sprayed with nine different materials, produced highest yields where a new material, zinc ethylene bisdithiocarbamate, a

readily wetting white powder, was tested for the first time, bringing 100 bushels more per acre than the unsprayed plots.

Extensive trials reported by the North Dakota station with some 33 materials for early blight and insect control gave better early blight control with sprays than with dusts. Zerlate was unsurpassed by any other fungicide tested in two places although Copper A was its equal in one location. DDT was effective in combination with both. In another series of trials Diathane-zinc sulfate-lime or Fermate gave somewhat better early blight control than the fixed copper sprays compared.

Potato scab control by chemicals has proved so unsatisfactory, in general, that every effort is being made to develop and introduce scab-resistant varieties. The Maryland station found that the Menominee variety, which has tubers resistant to both scab and late blight, yields well in that State. This variety was developed cooperatively by the Department and the Michigan station. Scab caused a loss of over 3,250,000 bushels of marketable potatoes in Michigan in 1945. In a station investigation in one area of this State, following a crop of sweetclover, potatoes were over 90 percent scabby while after rye or alfalfa the tubers were nearly all clean. From the New York (Cornell) station the cooperatively developed scab-resistant Ontario, Cayuga, and Seneca potatoes were released. These varieties are also somewhat resistant to late blight and the first two, along with Menominee, are resistant to a fusarium wilt (Z disease).

Potato ring-rot, which caused losses to Maine table stock growers of half a million dollars 6 years before, was negligible in 1945 following the use of practices worked out by station and Department scientists. The Colorado station has devised a simple stationary seed-potato cutting knife, covered continuously by flowing mercuric chloride solution, which equals the more expensive rotary knife in its effectiveness and speeds up the work 25 percent. This counts in a State like Colorado where around 38,000 days of man labor usually are needed to cut a million sacks of potatoes into seed pieces a year.

The Wyoming station cooperatively with the Department has released the ring-rot resistant Teton variety which has wide adaptability. The Maine station and the Department have found a number of seedlings that combine high resistance to ring-rot and late blight.

Fusarium seed piece decay can be prevented as shown by 4 years of tests by the New York State station on Long Island. The seed stock is treated with either oxide of mercury (1 pound to 30 gallons) or Semesan Bel (1 to 7½). This area pays out some \$3,500,000 a year for seed potatoes. In 1945, the treatment was used on 3,500 acres without a single case of field seed piece decay being reported. On 1,000 acres where treatment was not used the loss was 40 percent or more. In 1946, 53,000 acres were planted with treated potatoes.

Potato leaf roll virus infections were increased in Maine station and Department experiments where DDT was used because the foliage remained green longer on these plots and attracted the aphids which carry the disease. Community-wide use of DDT, however, may not involve this effect. Two new varieties out of some 7,000 strains of potatoes studied in Maine are so promising in resistance to leaf roll and commercial qualities that they are being increased for wider tests prior to release. The Colorado station method of detecting tubers

infected with leaf roll by ultraviolet radiation is being used by certain large eastern seed potato producers to help clean up their stocks.

Yellow dwarf virus infection has been found resisted in high degree, in field experiments of the Wisconsin station, by the varieties Russet Burbank, Warba, and Sebago. At the same time Green Mountain, Triumph, Russet Rural, and other varieties sustained heavy infection.

New potato diseases continue to appear. On three farms in Florida the station found a disease of potato tubers known as corky ring spot or internal brown spot apparently not reported before in the Western Hemisphere. Losses varied from a trace to 50 percent of the tubers. The precise cause is not yet known but a virus is suspected. The Oregon station announces the disturbing occurrence, in fields of potatoes grown for seed, of a previously undescribed stunting virus disease apparently spreading into the fields from some outside source and making the potatoes worthless for planting. Research is needed to find out how to deal with the disease before it becomes serious.

Rice leaf spot due to *Cercospora oryzae* is a serious cause of loss. The Department and the Arkansas and Louisiana stations have successfully cooperated in developing varieties resistant to the disease but in these States a new race of the fungus, race 6, has appeared to which a number of these new varieties are susceptible. Work was at once started at both stations to discover and introduce resistance to the new race and promising selections have already been found and are being increased to meet the new menace.

Rice seed treatment at the Arkansas station with Arasan, Phygon, or Spergon resulted in an average yield increase of 5 bushels per acre for three varieties.

Soybean seed treatment has not consistently justified its cost where high quality seed has been used. This is the conclusion of the Iowa station after 3 years of trials. New Improved Ceresan, though greatly increasing the stands of Lincoln soybeans in one test, caused a drop in yield perhaps due to prevention of normal nodulation. In 1945 equally good nodulation was present on plants from seed treated with Semesan Jr., Arasan, Spergon, or Ceresan. The North Carolina station, testing nine different materials on different lots of soybeans in different plantings, found for the third year that Arasan gave the most consistent although not large increases in stand, followed by DuBay 1452 F, PMA, and Ceresan. The Delaware station reported that 3 years' results showed no consistent benefit to stands or yields in two soil types from seed treatment with Spergon or Arasan.

Purple seed disease of soybean has been reported for the first time from New Jersey, where the station found up to 25 percent of the seeds affected in lots harvested in 1945, and from North Carolina where the station identified the cause as a seed-borne fungus, *Cercosporina kikuchii*, first recognized in the Orient, and found that Arasan seed treatment reduced the infection. It not only stains the seeds purple but attacks leaves, stems, and pods and kills seedlings.

Soybean foliage diseases may eventually be suppressed by dusting fields in areas where they cause serious damage. The North Carolina station found indication of a high degree of control of bacterial pustule, bacterial blight, and brown spot from properly timed applications of dusts containing copper. Nearly 5 bushels more per

acre were obtained as a result. Sulfur dusts, however, not only failed to control the bacteria but actually caused reduced yields. Dithane used as a spray in Delaware station trials injured soybean foliage.

Disease-resistant sorghums developed by experiment station work are estimated by a Texas station scientist to be adding \$30,000,000 annually to the income of Texas farmers. This estimate was based on the differences in yield obtained at the Lubbock substation from lines of milo resistant to pythium root rot and those not resistant.

Sugarbeet seedling blight damage has been greatly suppressed in Montana by the adoption by two large sugar companies on the Montana station recommendation, based on several years of research, that nitrogen-containing fertilizer helps seedlings pull through. In 1945 additional yields of 4 to 14 tons per acre were secured in experimental plots by this means and 3 to 5 tons in commercial fields. In 1946 the increase from fertilizer was worth over \$225,000 to Montana sugarbeet growers. The Ohio station found that fields where sugarbeets could not be grown because of seedling blight (black root) due to *Aphanomyces* and *Rhizoctonia* could be restored to productivity by the use of manure and superphosphate. The South Dakota station found that certain rotations favor and others suppress damage by *Aphanomyces*.

Disease-resistant sugarcane varieties developed cooperatively by the Department and the Louisiana and Florida stations have rescued the industry in the United States from ruin by plant diseases. It has been estimated that the replacement in Florida of susceptible types by mosaic-resistant sugarcane and sirup canes may well be worth 1½ million dollars to Florida sugar producers and 2 million to sirup producers annually.

Hot-water treatment of seed cane at 125.6° F. for 20 minutes for fall planting was found to increase sugarcane yields by 3 to 4 tons per acre in tests conducted on nine plantations over a 5-year period by the Louisiana station. This represents a money value of \$21 to \$28 per acre. This treatment completely eliminates chlorotic streak virus, stimulates bud and shoot growth, and reduces damage from pythium root rot.

Internal cork of sweetpotato is a new virus disease, discovered in 1944 by a scientist of the South Carolina station. It was found widely distributed and a potential threat to the \$134,000,000 American sweetpotato industry. It was named "internal cork" because it produces hard, blackish, corky spots in the sweetpotato flesh usually impossible to detect from the outside. It is vegetatively propagated in seed stock, increases in storage, and spreads in the field, probably through an insect carrier. Diseased leaves often show pale green spots or blotches, later usually ringed with purple. The disease seems to have little effect on plant vigor or yield. Since it occurs widely in a number of Southern States, a cooperative regional research program on the disease and its control is contemplated.

Sweetpotato treatments with Semesan Bel, bichloride of mercury, and borax before bedding at the Maryland station showed that while they control black rot, they cause injury. Spergon and Phygon prevented black rot safely and increased the number of healthy sprouts. Fermate, Tersan, Zerlate, Puratized, and Isothan Q15 did likewise.

Growers are now using Spergon. When the Mississippi station used borax (1 pound in 10 gallons) as a 10-minute soak, good black rot control was secured without cutting down the number of sprouts.

Sweetpotato stem rot or fusarium wilt attack was measurably delayed in Maryland station tests by using any of several fungicides in the transplanting solution. Puratized used in this way resulted in definite increase in yields. Dipping the sprouts in Tersan, Spergon, and Phygon before planting gave good protection against stem rot in New Jersey station experiments while Fermate was not so effective. Semesan Bel and Dithane, though effective, produced some root injury.

Sweetpotato scurf (*Monilochaetes*) was controlled without injury by Tersan, Fermate, Phygon, and Zerlate, in New Jersey station tests. Spergon did not control scurf well.

Soil rot of sweetpotatoes which may cause total crop loss in bad years in infested fields may be kept under control for 4 to 6 years by a single application of 600 to 700 pounds of sulfur per acre according to results secured over 8 years by the Louisiana station. Further lighter applications sufficient to keep soil acidity at pH 5 will continue the control. The Texas station is working for disease resistance and among 27 varieties grown on infested land found two lines, B-16 and T-4018, that showed no soil rot. L-12 showed high resistance.

Sweetpotato rots cause enormous losses in storage and afterward. Borax which the New Jersey station found effective cannot be recommended because authorities have not set a residue tolerance. In further research of all substitutes tested so far none have surpassed Sulfo-cide (containing sodium polysulfide) and lime-sulfur. To destroy rot-producing spores in sweetpotato stores and on the crates and baskets to be used, the South Carolina Edisto station found chloropicrin (tear gas) fumigation effective. It also killed rats, mice, and insects. North Carolina reports good results from this practice among growers.

Tobacco blue mold control by 15 percent Zerlate dust in Kentucky station experiments appeared excellent, equal to that produced by dusting the beds with 15-percent Fermate.

Eelworms of tobacco cause much more damage than is usually realized. The damage from the root knot eelworm has been found serious in certain southern tobacco areas but damage from the meadow nematodes is less readily recognized. Virginia station research, however, indicates that this type of eelworm causes widespread injury and also provides places of entrance for the black root rot fungus. Further research on this class of eelworms is greatly needed.

Disease resistant tobaccos developed by State stations and the Department, often cooperatively, have meant much to the American grower. Connecticut 15, a shade-grown black root rot-resistant type developed by the Connecticut (State) station since 1940, has been very successful. Havana 211 is a black root rot-resistant type developed at the Massachusetts station. This has increased the acre yields of this type of tobacco 150 to 200 pounds in the Connecticut Valley. The black shank resistant shade tobacco developed by the Florida station has saved the industry which otherwise would have disappeared. The gross value of this crop in Florida in 1944 was over \$4,000,000. A mosaic-resistant broadleaf type developed by the Tennessee station and Department received the highest grade on the market in 1945.

The Kentucky station Ky. 16 and Ky. 41A black root rot-resistant Burley tobaccos have produced exceptionally, yields of over 3,000 pounds per acre being common. This station has also produced Ky. 34, a variety resistant to fusarium wilt, black root rot, and mosaic which out-yields all other varieties. The adoption of the Granville bacterial wilt-resistant variety Oxford 26, produced by the North Carolina station and Department, on about 50,000 acres in 1945 is estimated to place the worth of this new strain at \$5,000,000 in a single year.

Wheat smuts no longer cause the enormous losses of the past because of the seed treatment methods and resistant varieties developed by the stations and Department. For example in Kansas during World War I stinking smut (bunt) losses averaged \$2,848,000 each year. In World War II the annual losses in that State dropped to less than one-tenth that figure.

At least 11 different races of loose smut have been identified through research at the Minnesota station. Of all the wheat types and varieties tested, Hope, Vernal, and Timopheevi proved to be the most resistant to them. Cooperation in study of loose smut races and resistance to them has been started by this station with workers in five States and the Netherlands. In Minnesota seed treatment of cereal grains and flax is estimated to have resulted in an increased return of more than \$6,000,000 in 1945.

Molds in moist wheat (16 to 35 percent moisture) were found responsible for starting spontaneous heating of the grain, according to the Minnesota station. *Aspergillus flavus* and *A. ochraceus*, particularly, caused rapid rise in temperature. This station tested some 80 compounds for ability to reduce mold development on damp wheat. Thiourea appeared to be the most promising. Chloramine-B and sulfanilamide came next.

INSECTS AS RELATED TO AGRICULTURE

There is no doubt as to the value American farmers, ranchers, and gardeners place on scientific measures of pest control developed by experiment station and Department research. In order to protect something like five billion dollars' worth of agricultural products each year, they spend an estimated hundred million dollars. Experience has proved that such expenditure is good insurance. American agriculture realizes that the only way of escape from devastating losses caused by disease and insect attacks is by applying effective measures of prevention worked out by scientific methods. Every passing year sees encouraging progress. Forged by State and Federal scientists, often working side by side, new and more successful weapons of defense are emerging. The following examples illustrate some of the recent progress made in insect research as related to agriculture.

TRUCK CROPS

Studies in many State experiment stations have reemphasized that DDT formulations are highly effective against certain insects, competitive with older insecticides against some, and ineffective against others. Station research has also shown that unexpected results continue to appear, that in many cases standardized recommendations cannot be suggested, and that DDT may be used successfully in combination with other materials.

In experiments with DDT on cabbage, squash, and potato by the Iowa station, 3 percent DDT dust controlled potato leafhoppers, flea beetles, and aphids; 1 percent failed adequately to control the flea beetles but was effective against leafhoppers and severely checked the aphids. At 0.25 percent it effected some reduction in leafhoppers and aphids. At the concentrations used, no toxicity to Irish Cobbler potatoes was noted. The imported cabbage worm was controlled as effectively by 1 as by 3 percent DDT; at 0.25 percent, it proved unsatisfactory. There was some evidence that 1 percent DDT was a little more efficient than 1 percent rotenone dust; average foliage damage and average yields were directly correlated in this experiment. The DDT dusts caused no injury to cabbage plants. Against the squash borer, 2 and 3 percent DDT dusts proved best among the concentrations used; neither 1 percent rotenone nor 8 percent calcium arsenate dusts were as effective as 3 percent DDT, which gave nearly complete control of this pest. The Hubbard and Buttercup varieties of squash exhibited no foliage injury from the treatment, but acorn squash and some muskmelon varieties were retarded in development, especially in their early growth stages.

In cooperative experiments by the Utah station and the Department on DDT for control of thrips in onion seed fields, plots treated with 10 percent DDT yielded 300 pounds of cleaned seed per acre as compared with 92 pounds for undusted plots. The dust was applied twice with a hand duster at the rate of 30 pounds per acre, the first treatment being made after the seed stalks had formed buds and the second 2 weeks later after the buds had opened but before blooming had begun. This work not only demonstrated the effectiveness of DDT against thrips, but also showed these insects to be a major factor in decreased onion-seed yields.

In an experiment reported by the Ohio station, DDT gave the most outstanding performance of any material used on onions during the past 15 years. Each application reduced to and maintained a very low level in the thrips population for at least 7 days. Three formulations were compared: DDT as a wettable powder, solubilized in an oil emulsion, and a 3 percent dust mixture; equally good control and yields were obtained with all three. DDT thus appears to offer practical and effective control of this pest, but additional information on dosage, residual efficiency, spray intervals, and other factors must be obtained for its most effective use.

The Idaho station demonstrated that control of thrips in onions grown for seed in the southern Idaho area is exceedingly effective when DDT is applied by airplane. The 1945 season tests indicate that a 10 percent DDT wettable dust applied at a cost of \$2.00 per acre by airplane resulted in an average yield increase of 168 pounds of onion seed per acre, giving an average net profit estimated at around \$150 per acre. Information from southern Idaho indicated that in that and the adjoining Oregon area probably 99 percent of the 1,200 to 1,500 acres to be devoted to onion seed production in 1946 were to be dusted by airplane.

Very successful results were reported by the Minnesota station in control of the six-spotted leafhopper in carrot fields by three to four applications of some of the newer insecticidal dusts, especially DDT, DDD (Rothane), sabadilla plus 35 percent of sulfur, and a pyrethrum-

sulfur combination. Best results followed treatment of the edges of a field with 5 percent DDT to prevent migration of the leafhoppers from wild vegetation. Furthermore, the 5 percent DDT dust applied two to three times gave excellent control of all three cabbage worms commonly found in the State, and a 3 or 5 percent dust applied to young radishes proved successful against flea beetles.

Blackheart or crown rot of celery is of major importance in the Waltham area of Massachusetts, losses of 50 percent of the crop being not uncommon. The injury is caused by a plant bug (*Lygus campestris*) not known to occur outside the State. Experimental tests with insecticidal dusts by the Massachusetts station resulted in producing 80 percent clean and marketable plants with DDT-talc dust (both 3 percent and 5 percent DDT) and 70 to 75 percent clean and marketable plants with sabadilla-lime dust (both 20 percent and 50 percent sabadilla seed). All untreated plants developed severe blackheart or crown rot. Reinfestation was prevented for 33 and for 14 to 19 days, respectively, by one application each of the DDT and sabadilla dusts. The question of DDT residues remains to be solved.

In the experimental plots and commercial applications used by the Maryland station with the Department, dry-mixed DDT dust and suspensions of DDT in water failed to give satisfactory control of the pea aphid, but all of the various DDT emulsion sprays tried gave excellent kills. Some formulations, however, caused serious plant injury; this was attributed to the direct action of the solvent or the emulsifier on the plant and to excessive amounts of one or the other of these ingredients. Emulsions of DDT in xylene, ethylene dichloride, and the aliphatic petroleum oils—in which minimum amounts of solvent and emulsifier were used—appeared to be safest on the foliage. DDT at 0.5 pound per acre in a water emulsion appeared to be ample for pea aphid control and in the tests reported was superior to the proprietary rotenone emulsion, Tubicide, at twice its recommended concentration and to the standard spray of ground derris root.

Basic copper arsenate was the most effective insecticide tried against the cowpea curculio, surpassing sodium-silico-fluoride, cryolite, and DDT in tests conducted by the Virginia station. A fungus (*Beauveria globulifera*) parasitizing the cowpea curculio practically eliminated it in the Chatham area, very few adults surviving the hibernation period of 1944-45. Smaller plantings, with more frequent picking, also aided in control.

In North Carolina the most injurious soybean pests are the velvet bean caterpillar, green clover worm, corn earworm, blister beetles, the native bean beetle, and the Mexican bean beetle. The last two seldom cause damage severe enough to justify treatment; blister beetles may be controlled by poison dusts; and leaf worms and corn earworms may be controlled with dusts of cryolite or combinations of cryolite with DDT, according to a recent study by the North Carolina station.

Weevil damage is an important problem where home-grown beans are stored for winter use; there is need for a common home preventive that is both cheap and readily available. In attempts to solve this problem, the Maine station obtained complete protection from unusually severe infestations by adding 2 teaspoonfuls of black pepper per pint of beans. One teaspoonful gave almost as good results, but the beans were ruined when the dose was reduced to half that amount.

Dusting with 20 percent sabadilla was found so effective by the Mississippi station that it could be recommended for controlling the southern green stinkbug and leaf-footed bug—pests on beans, cow-peas, okra, tomatoes, and other truck crops in Mississippi. The former occurs chiefly in the southern part of the State; the latter, in all sections. Since sabadilla also gave excellent control of blister beetles and the harlequin bug, it should prove of value in all home gardens.

Tests with an insecticide dust made from 50 percent ground sabadilla seed have proved successful in controlling the harlequin bug at the Tennessee station. This pest is difficult to kill with the more commonly used poisons, but when a 20-percent concentration was used there was a 100-percent knock-out of these insects in 5 minutes and all were dead within 15 hours. A 2.5-percent concentration gave a complete knock-down in 45 minutes and a 73 percent kill in 72 hours. A 5- to 10-percent concentration of ground sabadilla seed should result in effective control.

The Missouri station has noted a striking relationship between the amount of soil nitrogen provided for spinach plants and their resistance to attack by greenhouse thrips; as long as the plants made a luxuriant growth as a result of adequate nitrogen, they were practically immune to insect attack. Several points of interest in the interpretation of these findings are offered.

FRUIT CROPS

Effective control of the blueberry maggot was obtained by the Maine station in a 10-acre test plot by a dust containing 10 percent monohydrated copper sulfate, 40 percent hydrated lime, and 50 percent calcium arsenate, two applications being made at the rate of 6 pounds per acre. The harvested berries averaged only one maggot per 20 ounces of berries. Less effective control and more arsenical injury resulted when insoluble copper was substituted for the monohydrated copper sulfate, or when calcium arsenate was used alone. Maine blueberry growers are securing such good results with copper-lime-arsenic dust in large-scale commercial applications that the washing machines formerly used to separate maggot-infested fruit from sound fruit are no longer needed.

The grape cane girdler is an important insect pest of grapes in the home gardens of Massachusetts; against it, the usual insecticides have been ineffective. In laboratory tests by the Massachusetts station with freshly cut grape canes, none of those sprayed with DDT was girdled and no eggs had been laid on them. Beetles confined with DDT-sprayed canes lived half as long and made only one-sixth to one-fourth as many feeding scars as on canes sprayed with lead arsenate or cryolite. If the field tests now in progress confirm these laboratory results, a practical protection for this pest will have been found.

Three insects, the berry moth, leafhopper, and rose chafer, threaten the grape crop annually. Three or four applications of DDT will control the berry moth satisfactorily, Pennsylvania station results have proved, and vineyards so sprayed should not be troubled with leafhoppers or rose chafers. DDT was used in combination with bordeaux mixture and summer oil at concentrations of 10 to 12 ounces

per 100 gallons. Since the grape berry moth alone may injure 20 to 35 percent of the crop, DDT promises to be a valuable aid to the growers.

For codling moth control, DDT gave promise as tested in many localities. For example, the use of wettable DDT on Bartlett pears in the calyx and three cover sprays, according to the California station, gave better results against this pest than was obtained with standard lead arsenate in a regular five spray program. DDT was used at dosages of 1 pound actual DDT per 100 gallons in the calyx and first cover sprays and at 0.5 pound in the other two cover sprays; the arsenical dosages were 4 pounds in the first two and 3 pounds in the last three applications. Oil emulsion was added to the third and fourth arsenical cover sprays. DDT proved more effective than lead arsenate in preventing calyx worm entries. The populations of almond mite and Baker's mealybug increased very noticeably after applications of DDT.

DDT was outstanding as a substitute for lead arsenate against the codling moth in trials by the Virginia station. Benzene hexachloride (gamma isomer) was also more effective than lead arsenate although not so good as DDT against the larvae; the persistent odor will probably prevent its use after the fruits have attained the size of marbles. A spray schedule for DDT on apples was used extensively by growers in 1946.

Experimental results by the Colorado station showed that sprays containing DDT for use against the codling moth gave a smaller percentage of wormy fruit, but must be applied with additional materials if mites are also to be controlled. Four different spray programs based on station results were suggested for local growers.

Studies by the New York State station indicate that DDT is probably the most effective insecticide used against codling moth, though some failures have resulted because of poor timing and inefficient spraying.

A reduction in codling moth damage from 50 percent of the apple crop of West Virginia in 1945 to 5 percent in 1946 was forecast early in the 1946 season as a result of the general use of DDT in the spring of 1946. With an estimated crop of over 6 million bushels in 1946, valuable returns were expected, according to results from the West Virginia station.

From trials reported by the Maryland station, DDT in all combinations and at all but one of the strengths used (0.5 pound per 100 gallons) gave control of codling moth as good as or better than the standard sprays used as checks. Where DDT was used at the rate of 1 pound or more per 100 gallons of spray the percentage of clean fruit was approximately the same regardless of size of crop; this was not true for the standard spray schedules.

It is now possible to produce a crop of quinces almost entirely free from damage by the oriental fruit moth as a result of the development by the New York State station of spray programs based on DDT as the insecticide. Prior to its use, no effective control measure had been found.

The Michigan station found that the ordinary potato leafhopper, when permitted to feed on plum foliage, gives rise to a distinct dwarfing of shoot, spur, and leaf growth. The organs thus affected are more or less normal in appearance, except for the dwarfing, but the

net results are a stunted growth of the trees and serious interference with flower bud formation, fruit setting, and fruit production.

Both sprays and dusts consisting of lead arsenate, cryolite, and DDT were applied to the Tennessee station peach orchard, followed by counts and infestation records. In past years, cryolite produced injury on the mature peaches, but in these tests no injury was apparent. Cryolite effectively controlled the plum curculio, whereas DDT was of no value. While making infestation counts it was observed that DDT gave excellent control of the oriental fruit moth, a pest which in past years had not yielded to spraying.

Deformed peaches caused by suckling bugs are responsible for a large part of the culls in many South Carolina orchards. The tarnished plant bug was found on peach trees in Spartanburg County orchards from full bloom until petal fall, and available evidence indicates it to be largely responsible for the deformed peaches in that area; other bugs were present in very small numbers only. Preliminary tests by the Department with the South Carolina station indicated that jarring cannot be depended on to control these pests. In subsequent large-orchard tests, a single application of DDT at full bloom reduced the injured peaches at harvest from over 42 to less than 8 percent.

Ryanex and DDT were compared with each other, with natural parasitism, and with areas where additional parasites had been released by the New York State station for controlling the oriental fruit moth in peaches. Four sprays of DDT at 1 pound actual toxicant to 100 gallons applied at 3-week intervals greatly reduced the number of twig-infesting larvae and also the rate of parasitism; Ryanex had a comparable effect, though for a shorter period. The DDT provided superior protection to the fruit. Ryanex failed to give the residual action of DDT but should provide protection if used at shorter intervals. No injury to foliage or fruit was observed, but an infestation of red spider mite appeared late in the season in the DDT blocks.

Experimental plots in three counties where DDT had been applied by the California station at the rate of 1 pound actual DDT per 100 gallons to prunes and pears just before emergence of adult thrips gave much promise for its use in preventing thrips injury to developing buds. Although most of the fruit buds were beyond the stage where injury may occur when the peak emergence was observed, the thrips populations were definitely held in check by the DDT spray. Its use for controlling "white" thrips on pears in the petal-fall period of bloom provided good control in a large experimental plot of Bartlett pears, the dosage being the same as that tried for adult thrips.

Although sprays of DDT in various forms appeared promising for the control of black scale on olives, according to results from the California station, preliminary analyses of sprayed olives disclosed the persistence of large amounts of DDT residue for long periods of time, penetration of DDT into the fruit, and the presence of some DDT residue after the olives had been pickled in the regular commercial manner. These results suggest that spraying of olive fruits with any form of DDT must, at this time, be considered as hazardous.

Extensive experimental treatments by the California station have shown DDT to be effective against citrus thrips and citricola scale

in the central part of that State, but more information is needed as to its safety, proper formulations, dosages, and timing as well as on possible injuries to beneficial insects. Use of DDT in citrus orchards should thus still be considered experimental.

ORNAMENTAL PLANTS

Studies by the New York (Cornell) station have shown that, when used as a fumigant in vapor form, azobenzene appears to offer for the first time a satisfactory chemical control of red spider mite on roses, as well as an improved control on other florist crops. Although first made available commercially in November 1945, over 30,000 pounds of azobenzene powder have been purchased by growers and four companies are marketing the recommended formulation which contains 70 percent of the chemical.

The Massachusetts station obtained satisfactory control of red spider mite on greenhouse carnations by painting the steam pipes with a naphthalene base paste, thus eliminating the use of vaporizing equipment. Dosages of 0.6 and 0.8 ounce per 1,000 cubic feet for 6-hour exposures at 70° to 75° F. proved effective in the experimental trials. The kill of red spiders compared favorably with that obtained with azobenzene paste, which is effective but objectionable because of its bleaching effect on the carnation plants. When perfected, the naphthalene base paste treatment should permit appreciable savings in labor and equipment.

FIELD CROPS

Strikingly increased yields of legume seeds have been obtained with DDT applied at the proper time and in proper formulations. For example, alfalfa seed plots at the Utah station, when dusted with DDT to control lygus bugs, produced 400 pounds of seed per acre and commercial fields so treated produced 200 to 300 pounds of seed per acre. In 1925, Utah produced approximately 26 million pounds of seed; in 1944, only 16 percent of the 1925 crop. The average yield in 1925 was 382 pounds per acre; in 1945, 60 pounds per acre. Cooperative research with the Department to find the basis for these lowered yields has revealed the increase of lygus bugs in alfalfa fields to be an important factor. Until DDT became available, no insecticide had been found that would control these insects at an economically feasible cost. Trials with DDT during the last 2 years have demonstrated that this insecticide offers promise of greatly increased production of seed through the control of lygus bugs.

In experiments by the Idaho station, 25 pounds of 5 percent DDT dust per acre applied to alfalfa close to the blooming stage resulted in such excellent control of lygus bugs, which reduce seed setting, that a large percentage of infested fields grown for seed in the northern and southern parts of the State were to be dusted with this insecticide in 1946.

In recent seasons, outbreaks of a web-forming caterpillar on lespedeza in Virginia have caused some concern. Since no previous reference to this insect as an economic pest had been found, the Virginia station and the Department have presented information on its taxonomy, seasonal life history, and control and on the species of lespedeza attacked. The common name "lespedeza webworm" is proposed for it.

DDT mixed with shelled corn at the rate of 1 to 100,000 killed over 90 percent of the weevils in a month, according to tests by the Alabama station; DDD (Rothane) killed about 80 percent at the same concentration. Hydrated lime mixed with the DDT reduced its effectiveness; pulverized limestone did not.

In 1945 tests by the New Jersey station, 10 percent sabadilla dust and 10 percent DDT dusts applied at the rate of 100 pounds per acre gave over 90 percent reduction in hairy chinch bug populations. DDT also proved satisfactory when applied as a spray or incorporated with top-dressing applications.

In laboratory and cage tests at Waco, Texas, benzene hexachloride dust gave excellent results with several important cotton insects, according to the Texas station and the Department. Control of the boll weevil and cotton leafworm was better than with calcium arsenate. Its effectiveness against the cotton flea hopper, tarnished plant bug, and southern green stinkbug was equal to or better than that of DDT. Better control of the cotton aphid was obtained than with nicotine dusts, but DDT and heavy dosages of calcium arsenate dusts each gave better bollworm control than benzene hexachloride.

Flea-beetle control on potatoes, according to the Oregon station, was responsible for saving a large portion of the commercial Nettagem potato industry of Oregon during the war period when potatoes were in such great demand. Continued use of the control methods should also save potato-crop production in future years.

Wyoming station investigations in 1945 showed that damage to potato crops by psyllids and flea beetles can be greatly reduced by a combination of dusting sulfur and DDT (21 and 2 percent fused together). At Laramie, where only psyllids were troublesome the yield of U. S. No. 1 potatoes was 353 bushels per acre for the best treatment as compared with 256 bushels where the vines were not dusted. At Torrington, where both insects were troublesome, undusted plots averaged 123 bushels per acre of U. S. No. 1 potatoes, where the above sulfur-DDT formula gave 313 bushels.

Potato tuberworms have caused considerable apprehension and not a little loss to growers in New Jersey during the last two seasons, and particularly in the southern part of the State. As an aid in controlling these pests the New Jersey station has cooperated with the Department in importing two shipments of a parasite which attacks tuberworms. Each shipment contained about 180,000 parasites which were released in four areas where the tuberworm was suspected or known to be present. Subsequent check-ups will be made to determine how this parasite establishes itself in the release areas.

For potato pests under New York conditions, the New York (Cornell) station found that DDT gave adequate control of all major insects attacking the foliage. The quantities necessary in various formulations for satisfactory control were determined for the different species of insect pests. In both laboratory and field experiments, DDT proved compatible with all fungicides tried. Furthermore, though one of the outstanding attributes was its pronounced and prolonged residual effectiveness, chemical analyses of tubers from plants sprayed with DDT failed to show its presence.

When added to fungicidal dusts and sprays, DDT increased the yields of potatoes by 16 to 32 percent, respectively, in experiments by

the Maine station with the Department. It also increased the control of early and late blights when applied in combination with fungicides, gave excellent control of flea beetles, and killed 80 percent of the aphids. The organic compounds, Phygon, Dithane, and zinc carbonate, as well as neutral copper sprays, proved excellent as fungicides when combined with DDT. The results obtained warrant the belief that these fungicides with DDT may replace bordeaux mixture and calcium arsenate for potato spraying in Maine to give accompanying increased yields of 25 percent.

The New Hampshire station obtained excellent control of flea beetles, Colorado potato beetles, and tarnished plant bugs on potatoes with a copper dust containing 3 percent of DDT. Injury from aphids was prevented, but enough green peach aphids were present late in the season to serve as vectors of the potato leaf roll virus. Two pounds of DDT applied with 1,000 pounds of fertilizer to 1 acre of lawn in the spring reduced the Japanese beetle grub population by 90 percent, and few adult beetles were found in the area at the peak of beetle flight.

In both field and laboratory tests by the Nebraska station, DDT proved more effective than any other material used against potato insects. Trials were conducted with tuber flea beetles, potato psyllids, potato leafhoppers, green peach aphids, *Lygus* bugs, and leafhoppers. This material remained effective against psyllids and leafhoppers under field conditions for a relatively long period. Populations of some beneficial insects were also reduced, but no injurious influence on the plants was observed.

ANIMALS

The large-scale power dusting of feeder lambs developed by the New York (Cornell) station was found to offer an easy, rapid, and very effective control of the sheep tick on feeder lambs; it was devised for cold weather conditions, when dipping is injurious. The lambs are run through a chute past a bank of duster nozzles, a high-powered machine such as a 5-horsepower 18-nozzle crop duster being necessary. Under commercial conditions, 2,000 lambs can be dusted in a day at a cost of materials of about 1 cent per head. The most effective dust tried was a mixture of 1 part cube root (4.8 percent rotenone) and 10 parts Pyrax ABB, with 2 percent of No. 10 motor oil added. This preparation yielded over 90 percent kill of ticks in 2 days, with very little subsequent reinfestation during the feeder period. Dusts containing sulfur proved too irritating to the eyes of operators for practical use, and DDT was ineffective. The rotenone-oil dust in all cases gave satisfactory control without ill effects to the lambs, and the inclusion of oil weighted the material and reduced the dust cloud so that rotenone irritation to the operators was very slight.

The primary loss to dairymen by cattle grubs is believed to lie in the lowered milk production, especially during periods of warble fly attacks, according to studies by the New York (Cornell) station. The only practical control discovered consists of two dustings, the last one just before the cattle are turned out to pasture and the first about a month earlier; rotenone is the only insecticide known to be effective and pyrophyllite has proved a more efficient diluent than wettable sulfur. A dust composed of 1 part cube and 3 parts Pyrax ABB

gave satisfactory control. When all cattle within a small selected area were treated with this dust once in April and again in May, there followed a very appreciable decrease in the incidence of warble fly attacks and counts a year later indicated a marked lowering of the grub populations. Sprays containing DDT applied to the legs and underbodies before turning cattle out in spring proved of no value.

In tests by the Hawaii station to determine the comparative efficiency of various materials against damage to rabbit hides by larvae and adults of hide beetles (*Dermestes vulpinus* and *D. cadaverinus*), DDT proved outstandingly superior. In spray or dust form it provided excellent protection for at least 371 days after a single treatment and was equally effective on fresh or dried hides. No evidence of insect feeding was discernible on hides treated with 10 percent DDT dust or with 2, 3, 4, or 5 percent sprays before exposure to continual reinfestation by adults and larvae for 357 days; a slight but negligible feeding occurred, however, following treatment with 2, 3, 4, or 5 percent dusts. The maximum damage to hides treated with 1 percent dust or spray did not exceed 5 percent of the hide surface. Sprays proved more toxic to adults than dusts at the same concentration. Oviposition was not prevented by these treatments, but was inhibited in direct proportion to the DDT concentration used; sprays were more effective than dusts in preventing oviposition. DDT did not prevent eggs from hatching, but the emerging larvae died before they were able to feed perceptibly. All concentrations of dusts and sprays tried provided complete kills of the first-instar larvae.

Tests by the Delaware station of the effectiveness of various wire cloth screenings against mosquitoes showed 16 x 16 mesh to be entirely adequate except for brief periods when the test species (*Aedes taeniorhynchus*) was abnormally abundant; and 18 x 18 mesh gave complete protection. This information should prove useful in establishing specifications for the manufacture of wire screen cloth.

HONEYBEES

According to investigations by the Missouri station, sulfathiazole used at the rate of 0.5 gram in 1 gallon of sirup gave very effective control of American foulbrood of bees. Sulfaguanidine at the rate of 1 gram to a gallon of sirup enabled colonies to clean up all signs of infection, even when hived on 6 to 10 combs filled with decaying grubs killed by the disease.

The Connecticut (State) station, following the earlier discovery in Missouri, also found sulfathiazole useful in overcoming foulbrood in bees. Colonies fed this drug in sugar and water during the honey season overcame the disease and eliminated all scales and diseased brood in approximately 10 weeks; colony strength was also improved and surplus honey stored. Since the drug was found in the surplus honey, however, precautions are necessary to eliminate the product from the usual marketing channels. Further study of this method may provide a satisfactory alternative for destroying diseased colonies by burning, which costs Connecticut beekeepers \$8,000 to \$10,000 a year.

Observations and reports relative to DDT and its effect on bees were made when experimental treatments were applied by the California

station to alfalfa, cotton, nectarine, onion, and carrot and when it was used in mosquito control in Stanislaus and Los Angeles Counties. When applied to alfalfa in bloom, bees were either killed or driven from the fields for the first 2 days. There was no serious reduction, however, in the strength of the majority of the colonies in the vicinity of treated fields. Furthermore, DDT is not as injurious to bees as arsenicals when applied under similar field conditions; the same relationship seemed apparent when DDT was applied to the above-mentioned crops. No injury to colonies was reported from areas in which DDT was applied for mosquito control.

ADVANCES WITH INSECTICIDES

Although studies continue on such insecticides as DDT and on many of the older materials, various examples of which have been referred to in the preceding pages, each year numerous individual compounds and combinations, as well as new methods of application, are developed and tested by the State experiment stations to determine their possible usefulness under local conditions. This year, for instance, screening tests of polychlor compounds, including benzene hexachloride (1,2,3,4,5,6-hexachlorocyclohexane)—previously in progress at the New Hampshire station—were intensified to include studies on some 40 species of insects, following publication of the results of work in England with this new material. This chemical compound, also known in England as 666, was found to control many insects equally as well as DDT and to be effective also against some pests for which DDT has proved unsatisfactory. Many of the insects controlled by sprays or dusts of benzene hexachloride are important economically, including all species of aphids and thrips thus far investigated, adults of the Japanese beetle, grasshopper nymphs, chinch bugs in sod, and leaf-eating beetles such as the striped cucumber beetle. Because the material imparts an undesirable flavor it cannot in its present form be used on fruits except in the case of tomatoes.

Extensive field and laboratory trials of a new material, mentioned in an earlier report and known as Insect Repellant No. 612 (2-ethylhexandiol-1,3), was indicated by the New Jersey station to possess highly effective repellant properties against a variety of arthropod pests. Equally extensive toxicological studies and large-scale use by the armed forces have proved its safety and lack of irritant properties. Its physical and chemical characteristics are such as to make it easy and pleasant to apply and stable during storage or use. Workers at this station have summarized all available information relative to its physical, chemical, and repellant properties, its use in protecting against mosquitoes including the effects of varying the amount employed, application to clothing, its use against arthropod pests other than mosquitoes (stablefly, blackfly, sand flies, fleas, chiggers, and bedbugs), and its toxicological properties.

A chlorinated hydrocarbon known as 1068 was found by the Illinois station to be more toxic than DDT and to compare favorably in toxicity to one of the isomers of benzene hexachloride. Trials by standard entomological procedures were made on aphids, Colorado potato beetles, squash bugs, anopheline mosquitoes, cockroaches, and grasshoppers. Judged by the preliminary results, this material appears to have excellent possibilities.

Many petroleum products used in orchard spraying are obtainable by growers, but very little exact information relating to the safety and most effective type of oil for specific purposes had been available. Studies under way for a number of years at the New York State station have led to the general conclusion that oils with a paraffin base are usually most effective. Work at this station has progressed to the point where investigators have segregated the elements in such oils which are actually responsible for their insecticidal value. These results have a very practical bearing for agriculture.

Under laboratory conditions the California station found that despite the fact that the paraffinic and naphthenic oils were of about the same distillation range, the former was somewhat more effective against the California red scale when used at 0.25, 0.5, and 0.75 percent concentration in a precision sprayer. From the standpoint of distillation range, lighter oils were less effective than the heavier oils; raising the viscosity gave a larger deposit of oil, with a resulting increase in percentage kill of the red scale. There appeared to be no difference in the percentage kill by oils varying from 66 to 98 percent in unsulfonated residue.

Further studies of sabadilla were conducted by the Wisconsin station. The principal constituents of the seed were diluted at various levels with inert dusting material before testing for their relative toxicities to insects. The most toxic material proved to be cevadine, which gave a 50 percent kill for milkweed bugs at 1-8,000 and for grasshoppers at 1-2,000 and 1-3,000. Tests against grasshoppers indicated that activation of sabadilla dusts by heat or alkali appreciably increased their toxicity. Preparation of a concentrate with hydrated lime or use of this material as a diluent in the dust proved the easiest and most efficient method of activation.

A new terpene product (No. 3956) with insecticidal properties similar to DDT appears promising for mosquito control work. In experiments by the Delaware station this material proved as highly toxic to larvae and pupae of the test species (*Aedes sollicitans*) as DDT and had no adverse effects on other aquatic life when used at 0.2 or 0.4 pounds per acre. A dosage of 1.0 pound per acre, however, killed other insects, fish, and fiddler crabs. Further trials of No. 3956 on mosquitoes are in progress, as well as on apples, peaches, and vegetables for controlling various insect pests of these crops. An important feature of the treatment of areas against mosquitoes will be a study of the effect on muskrats, which represent a half-million-dollar industry in Delaware.

Because certain insecticides (including DDT and benzene hexachloride) apparently gain entrance to the insect body through the pupilli (pads) on the feet, these organs have been the subject of microscopical study by the New York (Cornell) station. The fact that DDT in pure crystalline form can enter the body of the housefly through the pulvilli has been verified and the initial histological work on this organ completed. These findings should aid in explaining the observed specificity of the insecticides and possibly indicate more effective formulations.

Comparative tests of D-D mixture and ethylene dibromide at the California station indicated these fumigants to offer good possibili-

ties for economical control of wireworms when applied in continuous streams at depths of 6 to 8 inches at 12- to 15-inch spacings. With D-D mixture, 40 gallons per acre gave satisfactory control and increased the yields of lettuce and beans. Simultaneous applications of 35 pounds of anhydrous ammonia with 40 gallons of D-D mixture in the fall gave the greatest increases in yields of lettuce the following spring. Ethylene dibromide at both 30 and 40 gallons of 10 percent strength by volume in a naphtha-200 thinner per acre gave good kills of wireworms and increased both stands and yields.

Wheat bran and combinations of citrus pulp with sawdust or cottonseed hulls proved the most effective of 24 materials tested by the Oklahoma station as bait carriers for grasshopper control. Straight sawdust was 68 percent as effective as bran, and addition of any form of bran increased its value. Cottonseed hulls were about equal to sawdust as a carrier when used alone or with bran. Alfalfa leaf meal added to cottonseed hulls or sawdust failed to increase their effectiveness; its combinations with bran were less satisfactory than similar mixtures of bran with cottonseed hulls or sawdust. In preliminary tests, rice hulls and cane pulp proved unsuitable—either alone or combined with bran. Over periods of several days there was little difference between the value of bran-water and bran-lubrication oil baits; all baits containing low-grade fuel oil were distinctly inferior to similar carriers containing water or lubricating oil.

Sulfur is a good insecticide for the control of aphids, provided it comes in actual contact with them at temperatures of 70° F. or above, according to Arkansas station findings. Sulfur is cheap enough to be used as a diluent for insecticides like rotenone and materially increases their efficiency.

Ryania dust—obtained by grinding the dried wood of the tropical *Ryania speciosa* discussed in the 1945 Office report as showing promise—again proved a valuable insecticide for certain insects, particularly the European corn borer, according to New Jersey station results. More than 40 tons of this dust were sold in that State in 1945. Growers using it increased their acre profits by \$100 to \$150 over untreated acreages. One commercial firm offered 200 tons of the dust for sale in 1946.

The Connecticut (State) station found a 50-percent Ryania dust highly effective against the European corn borer, proving as good as a 1-percent DDT dust and better than the two organic insecticides, DDD and benzene hexachloride.

Loss of toxicity by residues of DDT, according to studies by the Connecticut (State) station, may be caused by actual removal of DDT by insects and inactivation of the surface of the deposit by a coating of inactive material. After these inactivated deposits had been washed with benzene, they again became toxic.

Cooperative studies by the Connecticut (State) station with the Department have shown that concentrated insecticides may be used advantageously against pests of forests and shade trees, and that they may also prove useful for controlling insect pests of agricultural crops. A mist blower and a helicopter were used in the 1945 trials for applying a solution of 1 pound of DDT in 1 quart of xylene and 3 quarts of kerosene. The usual treatment was at the rate of 1 gallon.

per acre, or 1 pound of actual DDT. Good control of the gypsy moth and of canker worms was obtained by either blower or helicopter, with excellent results also against mosquitoes. On potatoes, control of flea beetles and leafhoppers was quite effective, but the results were less satisfactory for aphids. The great advantage of applying concentrated insecticides as a mist was shown by the fact that 1 gallon of the concentrated DDT mixture accomplished the same results in treating an acre of forest as 5,000 to 10,000 gallons of lead arsenate spray.

The Maryland station has recently designed and field-tested several traps—using DDT as the killing agent—that do not require emptying out the killed Japanese beetles. The results indicated DDT in either liquid or solid media to be effective, consistent kills of 100 percent being obtained in several tests. A satisfactory liquid medium may be prepared by mixing a saturated solution of xylene and DDT, one part, with one part each of deobase oil and light white mineral oil. A modified bait bottle equipped with a wick arranged to provide a contacting surface of about 1-inch diameter proved efficient for dispensing the liquid and killing the beetles; the average kill with this equipment for 18 observations was over 98 percent.

Tests by the Connecticut (State) station of diatomaceous diluents for insecticidal dusts revealed two new diluents that are nonabrasive and substantially better in toxicity than the standard pyrophyllite. When used with these materials, 0.5 percent rotenone proved as effective as 1 percent rotenone with pyrophyllite. A further advantage lies in the nonabrasive character of the diatomaceous diluents as compared with the very abrasive pyrophyllite.

HUMAN NUTRITION, FOODS, TEXTILES, AND HOME MANAGEMENT

A survey of research progress, as outlined in published and unpublished reports of the year's work of the experiment stations, indicates that work on the nutritive values of foods has continued to offer a rich field for investigation. This is not surprising considering the great number of foods and their natural variations; the new foods that are introduced or are developed by breeding, the constant development of new processing procedures, the significant number of nutrients that are known to be important in human nutrition and the new ones that are being discovered, and the constant development and improvement in methodology which affords a new approach to food investigations. The influence of these various factors is evident in the scope of the work on nutrients in foods reported within the year. This information on food values along with that on food production and consumption can give an over-all picture of how well the nation is fed.

Basic to any estimate of food needs, however, is a knowledge of the human needs for specific nutrients, how they are utilized by the body, and how much of them is required. The need for this basic information toward revising present estimates of nutrient allowances has been appreciated by station research workers as indicated by the increased number of nutrition investigations reported in the past year.

Methods, problems, and new developments in the field of food preservation have received attention, with greatest emphasis on preserva-

tion by freezing, and a few studies have dealt with problems of food preparation.

Outside the field of foods and nutrition, other studies that have particular importance for the home and the homemaker have been conducted on textiles and on problems of home management. The few textile researches have dealt with questions of use, serviceability, and care. As evidenced by an increased number of reports over those recorded in the past 3 years, there has been increased interest in home problems concerned with the over-all phase of management, including family economics, home equipment, time expenditures in homemaking, and the very pertinent question of housing.

The researches of the past year have included independent investigations by individual stations and also many cooperative studies. The Southern Cooperative Group has continued its research program on variations in the composition and nutritive value of vegetables grown in the South, and at the same time has participated in the National Cooperative Project, Conservation of Nutritive Values of Foods. The latter project has continued to operate on the regional and the key-commodity bases as outlined in the 1943 report (pp. 73-75), and the Southern, Western, and North-Central groups have held regional meetings to report progress, discuss problems of sampling and methodology, reach agreement on the over-all plan of commodity reports, and plan for new work and future approach. As an outgrowth of the key-commodity plan, workers concerned with the nutritive value of meat held a separate commodity conference to consider their very difficult and peculiar problems of sampling and methodology and to formulate the scope and plan of work for the meat investigations.

The North-Central cooperative regional project on the nutritional status of college women, sponsored by certain home economics sections of the experiment stations of the North Central States, has continued active. The eleventh research conference of workers engaged in this project was held within the year to edit manuscript material available and to plan for the completion of small pieces of work needed to round out the material for the final cooperative bulletin on this project.

NUTRIENTS IN FOODS—SCOPE OF INVESTIGATIONS

A check list presented on page 120 reveals that within the year there have been reports from 35 stations covering more than 100 investigations on nutrients in foods and on factors affecting the nutrient content. In general, the studies concerned agricultural commodities of importance to the region and included vegetables, fruits, cereals, and animal products in either the fresh or the processed state. A few of the studies were of the survey type as, for example, the Wisconsin station survey of canned foods to determine their content of some of the newer B-complex factors, namely, pyridoxine, biotin, and folic acid. Some of the values obtained in this study may be subject to reinvestigation with further developments in analytical procedures, but with methods presently in use canned salmon, yellow corn, and tomatoes were found to be good sources of pyridoxine, canned salmon the highest in biotin content, and the canned green vegetables highest in folic acid. Another survey study, not noted in the check list, was

that made by the Puerto Rico University station to determine the value as a source of riboflavin of 93 foods either produced or commonly consumed in Puerto Rico and the neighboring islands.

While some of the studies reported were of the survey type, most of them dealt with some particular phase of investigation such as the influence of varietal differences, environment, maturity, storage conditions, cooking, canning, freezing, dehydration, or other processes on the content of one or more nutrients. Of the latter, the vitamins received most attention—each food being studied primarily for those vitamins occurring therein in nutritionally significant amounts. In a few instances, mineral values, chiefly calcium and phosphorus, were determined, and a brief beginning was made toward evaluating the nutritional quality of food protein in terms of the content of essential amino acids. The one protein study of this type was concerned with mushrooms which on the basis of very early studies have been rated as having negligible protein value. The Massachusetts station obtained data by microbiological assay methods on the amino acid content of mushrooms. These results on the amino acid make-up of the mushroom protein together with other analytical data showing the mushrooms to contain about 2.7 percent of protein suggested that fresh mushrooms, while not comparable to such foods as meat and fish, are comparable to many fresh vegetables as a source of protein.

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See footnotes at end of table.

NUTRIENTS IN FOODS—RESEARCH METHOD OF INVESTIGATION

The research method utilized in these investigations on nutrients in foods is especially well illustrated by a number of particular studies.

Review of previous work to learn of positive and negative results obtained, of controversial and unsolved problems arising, and of methodology and techniques developed logically precedes any research undertaking in order to gain a picture of the new and unfinished work to be done and of the old work to be repeated for reevaluation by new and improved methodology. Pertinent bibliographies of such background material accompany most research reports but several annotated bibliographies prepared within the year by commodity chairmen in connection with the National Cooperative Project deserve particular mention because of their comprehensive nature and their classification and index features. These include a bibliography on spinach compiled at the Wyoming station with assistance of workers at the California, Colorado, Montana, Oregon, and Washington stations; one on the vitamin values for carrots compiled at the Colorado station; one on beef compiled at the Montana station with assistance from regional chairmen at the Texas and Indiana stations; and one on the influence of cooking processes on food nutrients prepared by workers at the North Carolina station with suggestions and aid from regional commodity chairmen at the New York (Cornell), Missouri, and Arizona stations.

Selection of a representative sample of the material or the population being studied is an essential step preceding actual analytical work to determine nutrient content. Because of the great variability of plant and animal material, the problem of adequate sampling often involves separate preliminary study. Such was the case at the Iowa station where it was found necessary to arrive at some decision as to what represented an adequate sample of apples for the estimation of mean ascorbic acid content. The great difference in the concentration of ascorbic acid of individual apples taken from the same tree, and the even greater differences in the ascorbic acid content of apples produced by different trees, showed the importance of using a large number of apples in a sample and of an equal distribution within the sample of apples derived from different trees. In addition, the apples from any one tree had to represent fruit picked from all sides of the tree because marked difference existed in the concentration of ascorbic acid in apples from the north and the south sides of a tree. It was found that the average concentrations of ascorbic acid in successive samples, each representing both the north half and the south half of each of 10 trees, were not statistically different from each other. A sample formulated on this basis, with the trees selected to represent the four quadrants of the orchard, provided a good base for evaluating the ascorbic acid value of apples from a given orchard.

In the sampling of tomatoes, as another example, the Nebraska station recognized the problem to be twofold: First, as to how many fruits should be analyzed, and second, whether the whole fruit needed to be analyzed or whether a fraction would suffice to give a reliable mean value. The latter point was important in relation to the saving of time and materials in the actual laboratory manipulations. As a result of a thorough study of sampling practices, it was determined that analysis of 20 tomatoes gave a mean ascorbic acid content which

was representative of the true mean of the lot and that analysis of either the whole fruit or a quarter cut as a radial sector or as a horizontal slice from the approximate center of the tomato resulted in a reliable mean value. This study emphasized further that individual tomatoes of the same sample differed so greatly in their ascorbic acid content that the range of values should also be reported along with the mean value and the standard deviation.

Analytical procedures for the determination of vitamins in foods have had to be developed along with researches to determine the nature and stability of the vitamins, how they are utilized by the animal, and whether they occur in the free or the bound form in plant and animal tissue. Actual use of the analytical methods in the hands of many workers and in application to many types of foodstuffs serves to test the general applicability of the procedures and leads to useful modifications and improvements, and even to the development of new methods. Such studies are at present a very essential part of the research on vitamins and amino acids in foods and many of the station researches, therefore, have been directed to problems of methodology.

A chemical method for the determination of vitamin A in whole dried eggs by use of chromatographic adsorption was developed by the Indiana station to take the place of previous chemical methods found unreliable and necessitating instead the use of the costly and tedious bioassay procedure. It is expected that the new method will be readily adaptable to the determination of vitamin A in other biological materials and will have wide application in the testing of food and feed products in both human and animal nutrition.

In a fluorophotometric assay of the riboflavin content of foods conducted earlier by the Massachusetts station, it was found that the recommended procedures were not entirely satisfactory with highly pigmented foods such as kale and baked beans. A comparison was therefore made of the biological, microbiological, and fluorophotometric procedures currently used in assays for the vitamin. The good agreement between certain modifications of these three methods, except in the case of the baked beans, indicated that one currently recommended step in the fluorophotometric procedure was responsible for marked error in the assay results. To eliminate the difficulty certain revision of the procedure was introduced; at the same time, it was found that both the fluorometric and the microbiological procedures could be simplified in certain respects.

Sample extraction and preparation procedures were devised or modified as a result of a number of investigations including that of the Wisconsin station on the preparation of samples for the microbiological assay of pantothenic acid; that of the Pennsylvania station on the use of 6 percent metaphosphoric acid as the medium of preference for stabilizing the ascorbic acid as extracted from peas in the Waring blender; that of the New York State station on the indophenol-xylene extraction method for ascorbic acid and modifications for interfering substances; and that of the Wisconsin station on the liberation of compounds in the folic acid group. These are but some of the studies on methodology that have been necessary as part of the research on the nutrient content of foods.

The calculation of results of analytical determinations is often complicated by attendant changes in the sample in the course of analy-

sis or by other complicating factors not necessarily anticipated until after preliminary test runs have been completed. In such cases, further research is indicated to determine the proper basis for chemical calculations. The problem of calculating the amount of the carotene retained by carrots in the blanching step of various processing methods involved a special study by the New York State station to determine the best basis for expressing the calculated results. As a result of this technical study it was recommended that alcohol-insoluble solids, rather than total solids, be used as the basis for calculating vitamin values for carrots. Application of the method to other vegetables was also suggested.

Interfering factors in the calculation of retention of nutritive value of foods were investigated in a special study at the Tennessee station in connection with estimations of cooking losses in institutional cookery practice. The findings, primarily of interest to the technical worker, indicated that retentions on a dry basis cannot be measured by data taken at various steps in preparation unless the only change has been a moisture change, and that they cannot be measured on the wet basis unless there has been no change in dry weight. In order to calculate retention, data must include total weights of all component parts at each stage of sampling. Incidental to these results, was the finding that added fat cooked with leafy vegetables such as cabbage and spinach did not have any effect on the retention of the ascorbic acid in the greens.

Repetition of experiments with or without pertinent variation in procedure is the rule rather than the exception in studies of nutrients in foods because the variability from sample to sample, from place to place, from season to season, and from treatment to treatment suggests the advisability of determining the range of variation and of basing any generalizations on more than a single test. The New Mexico station, for example, repeating the carotene and ascorbic acid determinations on carrots as obtained from successive spring and fall plantings over a 2-year period found that a gradual increase in carotene occurred during growth in all plantings, but that the very high values of the spring carrots were not reached by the slowly growing fall carrots.

In another series of experiments as carried out by the Minnesota station, different vegetables were found to respond differently to various methods of cooking insofar as ascorbic acid retention was concerned. The results collected so far indicate that general statements comparing the effects of methods of cooking upon the retention of ascorbic acid in vegetables are misleading, for the vegetable itself and the method of preparation for cooking influence the retentions. Thus, the present year's work shows that peas, boiling-onions, and cabbage retain a greater proportion of their original ascorbic acid when cooked in a tightly covered pan, pressure saucepan, or steamer, than when cooked in boiling water, while green beans broken into 1-inch lengths retain the same proportion of their original ascorbic acid regardless of the method of cooking. On the other hand, if the beans are prepared for cooking by cutting into narrow lengthwise strips, cooking in a tightly covered pan, pressure saucepan, or steamer again retains more ascorbic acid than cooking in boiling water.

Cooperative research as practiced in the closely integrated research program of the Southern Cooperative Group and in the coordinated program of the National Cooperative Project has offered an approach which has expedited the solution of problems. Illustrative of the Southern Cooperative Group work is the recently reported study on lima beans which was cooperatively planned and executed by the Virginia, Georgia, Mississippi, South Carolina, and Virginia Truck Experiment stations and the U. S. D. A. Regional Vegetable Breeding Laboratory. The experiment was planned to determine the effects on nutritive value of such factors as variety, location, bean maturity, plant maturity, storage, and cooking and was further designed to admit of statistical analysis of the data. Lima beans of two varieties were each grown at the several locations from a common seed source under similar conditions of cultivation, harvested at agreed-upon stages of maturity of beans and plants, and analyzed by the same chemical procedures. Storage and cooking tests at the several locations were carried out under similarly controlled conditions. These controlled repetitions of the experiment from place to place with an effort to reduce station to station differences to a minimum served as necessary replications in the hands of several investigators simultaneously rather than in the hands of one investigator over a period of years. This approach permitted extensive results to be obtained in a comparatively short time, with the additional advantage of gaining information on the effect of environmental influences.

The approach followed in the National Cooperative Project has been a closely coordinated one designed to obtain an over-all picture of factors affecting the nutritive value of foods. According to this plan, individual stations agree to investigate various phases of a study, keeping in mind the over-all objective, agree to follow similar chemical and sampling methodologies insofar as practicable, and to pool the results of their independent studies toward giving a composite picture of the influence of many factors on the various foods. From the check list (pages 120-124), which is based largely on studies conducted under the National Cooperative Project, it is apparent that within the year this coordinated group attack has contributed much information on the problem of conserving the nutritive values of foods.

NUTRITION INVESTIGATIONS

Dietary habits and nutritional status, when evaluated with respect to each other, afford an over-all appraisal of the benefits of applied nutrition teachings. The benefits of a school lunch program, for example, were observed in a South Carolina station study and again in a study by workers at the Florida station. In the former study, children in two rural elementary schools in the upper Piedmont of South Carolina were observed for about 1½ years during which time the children in one school received in the winter sessions a complete hot lunch, while children in the other school received only a partial lunch consisting of foods that could be served without cooking. These lunches were in addition to the home food supply. A higher proportion of the children in the complete lunch group than in the partial lunch group made unusually good gains in height, and by the end of the period had the outward physical signs of good nutrition as observed by an experienced pediatrician. A somewhat larger pro-

portion of the children receiving the complete lunch than of those having a partial lunch at school improved the trend of their physical growth and development, and a smaller proportion of them lost ground during the period of the study. The former group also maintained hemoglobin levels, whereas the latter group had hemoglobin values significantly lower at the close than at the beginning of the study. The investigators point out that the school lunch, while it alone cannot correct long-standing malnutrition, can play an important role in immediate improvement in the food intake of school children and in the nutrition education program which should have far-reaching and lasting effects.

The relation of diet of the Florida school children to tooth and bone structure was followed over the period 1941 to 1945 in children in certain schools. Roentgenological and dental examinations at the beginning of the study showed that about 70 percent of the children 6 to 10 years of age had some degree of retarded development of the wrist bones, about 80 to 85 percent of them had dental caries, and about 75 percent of them gingivitis. All the children showing severe caries and delayed development of the wrist bones were given special diet supplements. The continued yearly examinations showed that with improved diet there was progressive improvement of the wrist bones, and that by 1944 the dental caries and gingivitis had greatly decreased.

Adults also may benefit by improvement in dietary habits as observed in a study at the Iowa station of women in the fifth and sixth decades. Metabolism studies determined what the daily needs of these older women were for calcium, phosphorus, and nitrogen. A study of their customary self-chosen diets, containing only 1 cup of milk daily, showed that these diets did not adequately meet the individual body needs for the above elements. However, improvement of the diets merely with additional milk increased the intake and simultaneously the retention of these nutrients.

A dietary study by New York (Cornell) station workers of Cornell University women living under several different circumstances determined what their food intakes were over sample weekly periods. From this information on the foods eaten, the intake of specific nutrients—calories, protein, vitamins, minerals—was calculated and compared, not with the determined needs of the individuals, as was done in the Iowa study, but with the daily allowances recommended by the National Research Council. An examination of individual weekly averages showed that for all nutrients the intakes of all women were within the figures used for minimum requirements, which were taken as two-thirds of the National Research Council's recommendations. While all the diets met this test for minimum adequacy, certain groups, such as those in campus-controlled cottages where meals were served in a central dormitory, were better nourishment than others. Survey of individual food records for the intake of specific foods, such as milk, meat, eggs, vegetables, etc., indicated that many of the diets could have been improved by wiser selection of foods.

The availability of nutrients from foods was studied with human subjects to determine if these foods as actually utilized were the good sources of nutrients that their analyses indicated them to be.

The availability of ascorbic acid in cabbage, for example, was investigated at the Iowa station where six college women served as subjects. These women, it was found, utilized the ascorbic acid in the cabbage as well as they did an equivalent amount of the vitamin supplied in the form of pure crystalline ascorbic acid. Similarly, the ascorbic acid in papayas and guavas was as well utilized as the synthetic vitamin by the eight men and six women who served as subjects in experiments at the Hawaii station.

The availability of iron in Hawaii-grown vegetables was also determined by workers at the Hawaii station where rats were used as the test animals rather than human subjects. The trials confirmed the superior quality of the iron of legume seeds for hemoglobin regeneration in the rat, and showed further that taro corms and taro leaves, both important items in the diet of Polynesians, had a high percentage of available iron. From a technical standpoint, it was of significance to learn that the percentage of food iron, soluble in dilute acetic or in dilute sulfuric acid, bore no relationship to the availability as determined by bioassay. Experimental studies of iron availability are usually carried out on rats because of the difficulty of clinical investigations of this type. The advisability of repeating the work with other species was recognized by workers at the Wisconsin station who worked out a satisfactory technique for the use of the dog for studies of iron availability. In the course of this study, it was observed that the iron in bran was almost completely available, while that in spinach was only 20 to 40 percent available, as compared with the iron in ferric pyrophosphate.

The accessibility of vitamins in bakers' and "nutritional" yeasts was investigated at the Wisconsin station in tests on human subjects and also on rats which in these trials were found to respond similarly to the human subjects. It was shown that if the yeast cell was killed by boiling or by the process used in the commercial preparation of dried "nutritional" yeasts both the riboflavin and thiamine were released so that they could be utilized by the animal body. Live yeast as dried for bread making yielded a part of its riboflavin but practically no thiamine, while fresh compressed yeast ordinarily procurable withheld both its thiamine and its riboflavin from absorption in the human digestive tract and, further, took some thiamine from other digesting foods. These findings indicate that large sums of money have been spent by the American public on unavailable vitamins in compressed yeast.

The ability of the cow to transfer fluorine from forage, feeds, and drinking water to the milk becomes of importance in human nutrition because of the toxicity of fluorine in food supplies. The Arizona station was interested in this problem because many Arizona waters that cows might normally drink contain fluorine. In the experiments carried out, cows were given drinking waters containing from as little as 0.2 p. p. m. of fluorine to as much as 500 p. p. m. Analyses of the milk from these cows showed that there was a small but definite increase in the fluorine content, but that in no case, regardless of the fluorine content of the drinking water, did the fluorine content of the milk exceed 0.5 p. p. m. These results suggested that fluorine is not transmitted in toxic quantities to milk even when the lactating cows

are drinking water with a fluorine concentration far above that causing mottled enamel in children's teeth.

In continuance of this study of fluorine in foodstuffs, cereals, legumes, and vegetables were grown in soils artificially treated with fluorine compounds to concentrations of 500 to 3,200 p. p. m. of fluorine. While the fluorine concentration of the resulting plants was higher than that of plants in control plots receiving no fluorine, the amount deposited was not proportional to the amount in the soil. Since natural soils contain only traces of fluorine and since the excessively enriched soils produced relatively small increases in the plant fluorine content, it appears that plant foods grown on Arizona soils are not dangerously high in fluorine content. Vegetables cooked in water containing added fluorine were found to absorb some of the fluorine, suggesting, therefore, that it is not a wise policy to cook in fluorine waters cereals, beans, and other dry foods that absorb large amounts of water during the cooking process.

The relative efficiency of proteins of different origin for meeting the needs of the animal body for growth, reproduction, and lactation is determined by feeding trials with experimental animals, usually rats, receiving the protein food in question as the sole source of protein in the diet. The use of this method at the Arkansas station in an investigation of the biological value of brewers' yeast and of cultured yeasts showed that certain strains of these yeasts in addition to furnishing an abundance of the vitamin B complex were excellent tissue builders when used as the only sources of protein in the diets of rats throughout three generations. Possibilities were visualized, therefore, of using yeast for food in world populations faced with shortage of protein foods. It was realized of course that yeast would never be used as a meat substitute, but as a dietary supplement to fortify grains, for example. The value of such supplementation was tested in experiments that showed that blends of yeast at the 1-, 3-, or 5-percent level with enriched white flour, corn meal, or polished rice increased the biological value of the protein of the mixture over that of cereal alone as judged by growth response of rats. Incidental to this study, it was observed that the proteins of polished rice were far superior to those in enriched white flour.

It is recognized that the nutritive value of a protein or mixture of proteins is dependent upon the amino acid make-up of the protein. Within very recent years developments in protein chemistry along with nutrition investigations have established the fact that there are certain "essential" amino acids, namely, those that cannot be synthesized by the animal at a sufficiently rapid rate from any substance in the diet. It appears further, therefore, that the biological value of a protein is limited by the relative proportions of essential amino acids contained in it. This suggests the desirability of analyzing foods for their content of essential amino acids, but such investigations have been handicapped by the lack of adequate analytical methods. Now that methods are available, although subject to further development and improvement, a limited beginning has been made in evaluating foods in terms of the amino acid make-up of their proteins. At this research stage, however, it is not so clear that the amino acid make-up of a protein is the only big factor limiting its utilization within the body.

Investigators at the Illinois station have, therefore, concerned themselves recently with a study of the relationship between the amino acid constitution of proteins and their value in animal growth by comparing the amino acid contents of certain food products as determined by modern methods, with the results of rat-feeding experiments designed to detect the amino acids limiting the protein value in the nutrition of growth. A method worked out for the computation of results involved estimating for each protein the percentage deviation of its contents of each essential amino acid (per 16 grams nitrogen) from the corresponding contents of a protein mixture, such as eggs, almost completely digested and well utilized by the rat. The amino acid limiting the value of a protein was thus revealed as the one whose percentage deficit from the standard protein (egg) was the greatest. In the 28 proteins and protein mixtures investigated the limiting amino acids thus indicated agreed with those determined in feeding experiments with only one or two exceptions. This method of evaluating protein quality gives promise, therefore, of usefulness to investigators who will continue the comparatively new approach to the work of determining the relative values of foods as sources of protein.

Information on the metabolism of nutrients, that is, on what proportions are excreted and retained in relation to the amounts absorbed from the digestive tract, is essential background information for determining the nutritional requirements of people of different sex, age, and activity. The dietary allowances recommended by the National Research Council as a working basis in planning diets and food supplies were formulated in considerable measure from available metabolism data. The allowances formulated in 1941 and subsequently revised are admittedly tentative for certain nutrients and subject to revision as increasing evidence becomes available. Data published within the year as the result of various metabolism studies at the stations will contribute measurably to this evidence.

Investigations by workers at the New York (Cornell) station on the calcium, phosphorus, and nitrogen metabolism of preschool children studied in successive periods over many weeks yielded data on the retentions of these elements, each as fed at several levels in the basic diets. These results were of value in assessing the young child's requirements for these nutrients. However, the variation in retention between children, and between different dietary periods for the same child suggested that factors other than diet alone regulated the retentions of these elements. Because of this child-to-child and period-to-period variation, Illinois station workers extended their studies of the calcium requirements of seven preschool boys over the very long period of 40 weeks, during which time calcium balances were determined at different levels of calcium intake. Values believed to be representative of the daily needs of each child were obtained. These values and further data on the rate at which each subject could utilize the calcium of milk gave figures for the food calcium requirements of each child; the values ranged from 35 to 57 milligrams per kilogram of body weight per day. These figures translated in terms of food indicated that with 300 milligrams of calcium per day from nonmilk foods, six of the children would have needed a milk supplement of 2 cups while one child would have needed 3 cups.

This variability in calcium metabolism and calcium requirements was also observed in adult subjects studied by another group of investigators at the Illinois station. On the basis of long-time metabolism studies of 19 men receiving a good diet, in which milk products or equally available calcium salts furnished 60 percent of the calcium intake, a value of 10 milligrams per kilogram of body weight per day was obtained as an average for the human adult calcium requirement. The investigators point out that such an average is of value in planning diets but that it is only of subsidiary value in forming decisions as to calcium undernutrition in a community. Because of the great adaptability of the human organism to wide ranges in calcium supply, individual or community intakes of calcium may fall markedly below the average requirement value and not indicate calcium undernutrition unless there is clinical or laboratory evidence of draining of minerals from the bony structure of soft tissues.

Studies of adult calcium metabolism by this latter group of Illinois workers, and likewise the several studies by the New York (Cornell) workers on calcium, phosphorus, and nitrogen metabolism of preschool children, brought out the fact that neither ascorbic acid, citric acid (or sodium or potassium citrates), nor the equivalent in orange juice fed as diet supplements, influenced the body's retention of calcium, phosphorus, or nitrogen. Experiments at the California station showed also that ascorbic acid had no influence on the beneficial course of iron therapy given to a group of children with low color index anemia accompanied by a borderline ascorbic acid status.

A comparison of thiamine synthesis and excretion in human subjects on synthetic and natural diets, led New York (Cornell) station workers to the conclusion that the recommended daily thiamine allowances for women might be lowered to 1.1 or 1.2 milligrams per day. This conclusion seemed logical considering the thiamine excretions of the women subjects, and their apparent well-being on intake of 0.84 to 1.00 milligrams of thiamine daily. A similar study on riboflavin gave less conclusive results than did the thiamine study, and suggested that excretion studies add information concerning riboflavin metabolism but do not give the answer to the question of riboflavin requirement.

Sweat, as an avenue of escape of nutrients absorbed through the intestinal tract, has not received very much attention. In connection with possible losses of nutrients through this avenue by men sweating at hard labor or in tropical climates, a series of experiments was carried out by Illinois station workers to determine the excretion of several vitamins in sweat and in urine by men subjected to comfortable, hot dry, and hot humid atmospheres. Studies on this problem reported within the year were concerned with the excretion of ascorbic acid and dehydroascorbic acid, inositol, para-aminobenzoic acid, pantothenic acid, and iodine. The data accumulated in these tests suggest that vitamin and iodine losses in sweat are small as compared to the daily excretion in the urine.

The basal metabolism of college women in several Midwestern States was investigated at the Kansas, Iowa, Minnesota, Ohio, and Oklahoma stations as part of the North-Central cooperative regional project relating to the nutritional status of college women. A previous study by workers on this project indicated significant differences

in the basal metabolic rates of college women in these States. In general, the basal rates were slightly lower in the warmest climates, yet the coldest weather did not always produce the highest rates. Because of this discrepancy, the study was extended to determine the effects on basal metabolism of season and associated factors. In this later study, 10 college women distributed in these 5 States deviating considerably in temperatures and other climatic conditions were studied over periods of 20 to 104 weeks for the different subjects. Individual tests ranging in number from 17 to 55 showed a good deal of variation for the same subject over the period of investigation. Although the response was not uniform, season was apparently a significant factor affecting the basal rate of 6 of the 10 subjects. Pulse, respiration, body temperature, outside temperature, humidity, and hours of sunshine were seemingly minor factors in the results obtained.

FOOD PRESERVATION—FREEZING

Varietal differences in fruits and vegetables were studied at the South Carolina station in relation to adaptability for freezing, and not all products were found suitable. The Louisiana station reported that, in general, vegetables which were commonly served raw as salads were unsuitable for freezing. Cantaloups, celery, cress, cucumbers, endive, lettuce, green onions, parsley, radishes, green peppers, tomatoes, and watermelons were so classified, and methods other than freezing were suggested for preserving artichokes, cabbage, herbs, onions, hot peppers, potatoes, and rutabagas.

The effects of preparation methods on frozen citrus hearts have been studied at the Florida station during the past year. The best samples obtained were prepared by precooling the fruit, peeling either mechanically or by hand, and subjecting to a slight vacuum which was broken with carbon dioxide gas before packaging. Studies made by the California station show that concentration of citrus juices may be accomplished by freezing to a slush then draining through a screen or cheesecloth. Concentrates made by this method gave the frozen product a fresher flavor than those made by the customary method of separation of ice and sirup by centrifuging. At the Tennessee station, fruit juice concentrates made of undiluted expressed juice containing 10 percent added sugar were stored for 1 year at 0° F. before examining, at which time they showed much of the flavor and aroma of freshly processed concentrate. Sweetened, frozen cubes made from the concentrates were of excellent quality. Investigations at the Texas station to study the effect of blanching Magnolia figs in steam at atmospheric pressure showed that peeling previous to blanching improved their appearance and flavor. The Georgia station has recommended two home and two commercial formulas for packing frozen Elberta peaches in which ascorbic acid as an antibrowning agent and citric acid as a stabilizer for the ascorbic acid are included.

Peas and snap beans blanched in hard water in preparation for freezing showed an increase in their calcium content according to work reported at the New York State station. Different types of blanching water were used in these experiments and other than this increase in calcium, no significant differences in the mineral or vitamin content were observed.

The Oregon station found that the defective flavors commonly observed in frozen corn-on-the-cob could be eliminated by drilling holes longitudinally through the cob to allow the blanching water or steam to enter the center of the ear and permit enzyme inactivation in at least 2 minutes' less time than was required for solid ears. The New York State station has recommended blanching periods for corn-on-the-cob according to the size of the ear. Factory and laboratory experiments conducted by workers from the California station show that water cooling and fluming of various fruits and vegetables was objectionable from the standpoint of loss of nutrients and damage to flavor, while air cooling avoided these objections and appeared to be practicable commercially.

Methods of freezing range from very slow freezing, such as that accomplished by ordinary mechanical refrigeration or freezer locker, to very rapid freezing by immersion in a freezing liquid. The length of time required for foods to be frozen solid depends upon the size and type of container, the nature of the product being frozen, and the quantity placed in the freezer at one time. According to the Louisiana station, the main difference in foods frozen at different rates of speed is in the size of the ice crystals formed within the tissues of the foods. In general, slow freezing of foods induced the formation of large crystals, whose size increased up to as much as 500 or even 1,000 times that of the cells. Workers at this station found that the formation of large crystals resulted in crushing and rupturing of cells so that, upon thawing, the food became soft, lost juice, and created conditions for enzymes to act upon cell contents. With peas and snap beans, however, the New York State station found that the speed of freezing by the home processor had little effect on the vitamin content, flavor, or texture of the frozen product. To facilitate freezing, this station has recommended staggering the packages to be placed in the home freezer to provide air space between each package, and has suggested limiting additional frozen material to be added to the freezer to 20 one-pound packages.

Experimental studies were carried out on rates of freezing in farm- and domestic-type food storage cabinets and in commercial locker plants at the Pennsylvania station. Data were obtained on vegetables, meat, and poultry packaged under various conditions employing single-plate and air-blast methods of freezing. The freezing interval varied from 2 to 12 or more hours, depending on the size of the package and number of layers of wrapping material. The New Jersey station reported that all stages of freezing preservation require very low temperatures. For initial freezing, temperatures of 10 to 20 degrees below zero are advisable, and there is no danger of having them too low.

Preserving mediums, such as sirups, added to fruits before freezing checks the action of enzymes in the fruit during storage and protects fruit which may be exposed to the air. The Tennessee station found that a mixture of equal parts of 50 percent white corn sirup and 50 percent granulated sugar sirup was satisfactory for the freezing preservation of peaches, and that a small amount of pure sodium bisulfite (0.01 percent) added to the dry granulated sugar or sirup before packing was effective in preventing browning. The Massachusetts station treated McIntosh apple slices with 0.03 to 1.5 percent calcium chlo-

ride solution before processing, and has recommended this method for overcoming the mushy texture usually found when this variety of apples is canned or frozen.

Little or no sugar is required in the quick freezing of fruits since the sweetening may be added as the product is thawed out for serving, according to the New York State station. Strawberries and raspberries may be frozen without sugar with reasonably satisfactory results, while sweet and sour cherries are satisfactorily preserved with the use of 10 percent sugar sirup. This station also reports that rhubarb preserved by freezing without the addition of sugar is superior in flavor and color to that preserved by the old practice of sealing in water in fruit jars. The Iowa station has suggested cutting rhubarb into 1½-inch pieces and freezing the fresh raw product instead of scalding or precooking it.

Repacking frozen foods was found practicable at the Minnesota station when commercially frozen blueberries, sweet cherries, apricots, and peaches, packaged in 20- to 35-pound containers, were repacked into heavily waxed containers for home use. Repacking was started when the ice crystals between the fruit defrosted sufficiently for individual pieces to be separated from the original pack.

Frozen cooked foods have been investigated by a number of stations during the past year. The Georgia station reported that proper selection, preparation, packaging, cooking times and temperatures, and rapid cooling are the chief factors contributing to better quality in cooked frozen vegetables. They found that closed containers were best for cooking vegetables to be frozen because volatile flavors, partially water-soluble, were retained. Large cuts of meats, such as hams, shoulders, roasts, and turkeys were preserved in excellent condition when precooked by boiling, baking, or roasting. Frozen cooked vegetables and meat sauces showed indistinguishable characteristics from unfrozen sauces after heating and thawing. Breads of all kinds baked and kept for several months in storage were successful. However, workers at this station recognize major problems in the complexity of freezing these cooked products, examples being separation of fats in gravies, stews, and sauces; precipitation of certain proteins, as in egg whites; starch break-downs as in spaghetti and potatoes; and the loss of fresh flavors and aromas due to oxidation.

Staff members at the New York (Cornell) station have presented recipes for preparing frozen cooked foods. These include vegetable dishes, soups, meats, poultry, combination dishes, salads, sandwiches, hors d'oeuvres, quick breads, yeast rolls, fruits, cakes, puddings, cookies, pies, and other desserts. Precooked vegetables when packed loose have been reported by the Washington station to be less desirable than those which have been heated just enough for proper blanching, covered with a cream sauce or meat broth, and then frozen.

FOOD PRESERVATION—CANNING

Canning studies made by the Massachusetts station show that this type of food preservation is cheaper than home freezing. Based on initial cost of \$30.00 per cubic foot for freezer capacity and including depreciation, power, containers, and storage, the unit cost for preserving a pound of food by freezing is approximately 18½ cents as compared with 4 cents for canning.

Beef canning experiments conducted at the Georgia station show that aging at 36° to 38° F. for 8 days previous to cutting and processing improves the texture and flavor. Of 54 lots of steaks, roasts, and stew meat processed at 10 or 15 pounds pressure from 60 to 90 minutes, there were no losses by spoilage that could be traced to under-processing. Processing at 10 pounds pressure developed the highest flavor and the best texture.

FOOD PRESERVATION—DEHYDRATION

Dehydration experiments with sweetpotatoes were continued this past year at the Tennessee station. The fresh sweetpotatoes were peeled, cut into slices and cubes, and then blanched in steam, and comparative tests of dehydration and freezing were made. Blanched sweetpotatoes held very well in frozen storage, while the unblanched frozen product lacked flavor and darkened somewhat. The blanched, partially dehydrated sweet potatoes retained good quality in storage at 0° F., and the completely dehydrated product retained quality after 6 months' storage at room temperature. Unblanched dehydrated sweetpotatoes were starchy and flavorless.

The Michigan station made a series of experimental studies on Montmorency cherries to determine the effect of enzyme inactivation prior to dehydration on the color retention and storage life of the dried product. They found that hot water blanches of 3 and 4 minutes' duration at 135° F. gave the most satisfactory product, but after 6 months' storage, even these cherries turned brown. Supplementary treatments were made, including the use of wetting agents, acids, salts, sugar, and liquid pectin. Workers at this station feel that further investigational work is necessary before dehydrated cherries will be able to compete economically with canned or frozen cherries in the pie trade.

Cooking and organoleptic tests on dehydrated products at the Iowa station indicated only fair preservation of flavor and quality in certain products as compared with the same products frozen. Apples, pears, corn, vegetable soybeans, and lima beans gave the most satisfactory dehydrated products on this comparative basis. Sulfite dips were investigated as a predehydration treatment for onions, carrots, and apples, and the products obtained were compared with those which had been subjected to scalding and fumes of burning sulfur. The sulfite dip gave better color retention and flavor, and apples and onions so treated remained a creamy white during storage and after cooking, while carrots retained more natural yellow color. Storage of these products at 20° to 24° F. or 50° to 60° resulted in a more desirable quality than higher ranges.

The same techniques as employed during the war for drying large amounts of penicillin and blood plasma by subjecting the materials in a frozen state to high vacuum were used by the New York State experiment station to "freeze-dry" fruits and vegetables. The frozen vegetables to be dehydrated were placed in a container where they were subjected to vacuum, and the moisture vapor given off by the material was drawn into a drum submerged in a mixture of dry ice and acetone which had a temperature of -100° F. The station scientists report that much study remains to be done to make the process practical as a method of food preservation, although results obtained thus far

demonstrated clearly the superiority of freeze-drying over the usual methods of dehydrating foods.

Studies with cold-mix dehydrated fruit spreads were continued at the Delaware station the past year. Gels of 45 percent soluble solids containing 50 milligrams of ascorbic acid per 42 grams finished gel were packed in sealed jelly glasses and stored for 19 days at temperatures varying from 25° to 50° C. Assays made at irregular intervals indicated appreciable loss of ascorbic acid; powders showed smaller losses than did the finished gels, suggesting that properly packaged gel powders may serve as carriers for vitamin C in the Army diet, providing proper storage temperatures are observed. Sucrose and dextrose were added separately or in various combinations with the other gel ingredients to give soluble solids above 45 percent in experiments to determine the means of dispersing high-methoxyl, intermediate-methoxyl, low-methoxyl pectins, as well as apple and citrus pectins. A total sugar content of 60 percent in the finished gel represented the highest limit of sugars, and on this basis, gel strength values were obtained showing that when sucrose was the only sweetening agent used a grainy texture developed. Gels were also made at this station by combining sweet-potato powder, dextrose, sucrose, commercial pectin, common salt, and spices. Other pectin studies have been reported by the Delaware station, including an experiment in which the extraction of certain fruit juices with the aid of polyphosphates improved the pectic quality of the juices in making jelly.

FOOD PREPARATION

Altitude cooking experiments, involving the use of tested recipes for cakes and corrections for their application in varying localities, were conducted at the Colorado station. Suggestions for measuring ingredients, equipment, and directions for general mixing and baking are presented in a bulletin published the past year by this station. The important features of altitude cookery, including the leavening correction, the sugar-water ratio as related to the type of shortening used, and baking temperatures are considered to be the important features of baking cakes and cookies when the problem of the structural strength of the egg and flour are involved.

The effect of different methods of combining the ingredients of a simple cake was investigated by the Kansas station. Batters with a wide range of consistency were obtained when the ingredients were mixed by the six methods used in the experiments, with each method tending to give a characteristic batter. Consistency and specific gravity were found closely related; cakes of low specific gravity yielded a tender, compressible product.

The tenderness of pastries made with different soya flours using a basic formula in three series of mixes containing various percentages of fat, were investigated at the Indiana station. The study furnishes evidence that the natural fat present in the flour is effective as a shortening agent in pastries made with soya flour.

Candies which were made with pectin, sugar, and either fruit puree or juice were prepared by the California station. The New York State station has studied the factors involved in the preparation of maple creams, a soft fondant made from pure maple sirup by boil-

ing rapidly until a temperature of 232° F. is reached, cooling rapidly to room temperature, and stirring until crystallization is complete.

Food substitute experiments were conducted at the New York (Cornell) station to determine the optimum extent to which cereals could be substituted for meat in ground meat loaves. In these tests, loaves made with soya grits as an extender scored slightly higher than those made with rolled oats or shredded wheat.

A formula was developed at the Missouri station for a loaf of yeast bread made of enriched flour, dried whole eggs, dried whole milk, fortified margarine, and yeast which would aim to furnish one-half of the daily nutritive requirements of a moderately active man.

TEXTILES

This year's report on textile research includes a study at the Ohio station on the selection of sewing thread. Different brands were observed to vary in price, balance of twist, seam strength, and color-fastness to laundering. Unmercerized cotton thread had the best balance of twist and caused least difficulty in hand sewing, while mercerized cotton and nylon threads were most poorly balanced and caused the greatest difficulty in hand sewing. Heavy duty cotton thread was outstanding in single strand strength, and it was the strongest when made up into seams, with nylon thread being next highest in seam strength. Research studies were also made at this station concerning the serviceability of 36 cotton and rayon glass curtain fabrics. Comparisons of the two types of fabrics showed that the cotton gave evidence of being more durable and serviceable than rayon fabrics of similar construction.

The physical properties of 13 blankets of varying fiber contents were determined in a study by the Kansas station. Blends of cotton and rayon, and of rayon, wool, and cotton, and an all-cotton blanket were found to be warmer than all wool ones, although in blankets of the same thickness, variations in protective value were small. It was also found that laundering and dry cleaning increased the protective value of wool blankets, but decreased that of the cotton ones.

The Montana station found that a nonsoap detergent used in either soft or hard water for washing 100-percent-wool blankets had better cleaning characteristics than soap. Part-wool blankets washed with soap in either soft, hard, or softened water were cleaner than those washed with the detergent. The nonsoap detergent used, sodium lauryl sulfate, was also applied in other washing tests, including infants' white woolen garments, linen napkins, cotton prints, and rayon wearing apparel. No significant differences were found in the effects of the soap and the nonsoap detergent on fabric strength and wearing quality, although soap had an appreciably greater cleansing value on cotton, linen, or mixed cotton and wool fabrics.

HOME MANAGEMENT

Time expenditure studies in homemaking activities at the Vermont station showed that the housewife spent an average of 64½ hours during 1 week on food preparation, housecleaning, dishwashing, and other activities. Persons other than the housewife gave an average of 17¾ hours to homemaking, with hired workers in 26 cases averaging 25½ hours for the week. In 9 percent of the homes, women and

girls of the family, other than the housewife, spent a total of 35 hours or more during the week on homemaking. Relationships between time expenditures and efficiency were found to be contributing factors to the allocation of time.

Eighty Negro and eighty white town families were interviewed by Mississippi station workers to ascertain the amount of time spent on homemaking activities. Analysis of the records showed that more time was spent by all groups in food preparation than in all other homemaking activities combined. Records kept by these 160 homemakers in the summer of 1943 revealed a total of 1,857 dishes prepared during the 1 week studied. Food preparation practices of each family rated according to the average number of good, poor, and fair practices per dish revealed that 29 percent had followed good preparation rules, 40 percent fair, and 31 percent poor. Through comparisons of the methods of preparation of 12 commonly used foods and through a study of new dishes tried during 1 year, findings suggest wide differences between white and Negro families in use and preparation practices and between families of varied socioeconomic status living in towns of different soil areas.

Family economics studies made from farm income and expenditure account books kept by 346 farm families during 1934 to 1940 have been presented in a bulletin this year by the Kansas station. The study showed that net farm incomes varied from \$958 in 1938 to \$2,057 in 1935. In most of the years studied, families with 5 to 14 members, consisting of husband and wife and 3 or more adults, or husband and wife and 5 or more other persons regardless of age, had the largest net farm incomes. Families with 2 members, consisting of husband and wife only, averaged the lowest income for the period studied, with the exception of 1935. The average value of living for all families was \$1,426.

A recently published study by the Wisconsin station of prewar and wartime incomes and expenditures for 106 Farm Security families was based on data for the years 1940 and 1942. Comparisons showed that wartime increases of gross income averaged 90.5 percent and net income 108.4 percent. Family living and savings, such as life insurance and war bonds, went up 71.2 percent, with an increase in expenditures for every commodity group—both in absolute amount spent and on the percentage basis. Allowing for increased living costs, however, the actual increase in family living was only 34.9 percent. Larger families reported less per capita expenditure for items other than food and clothing.

Workers at the South Carolina station interviewed 136 rural families of Pickens County, South Carolina, to obtain information relative to their food supply. Farm families were found to produce almost all of their food supply except sugar; the nonfarm families produced more than 50 percent of all their foods except sugars, fats other than butter, cereals, dried legumes, and nuts. Approximately 15 percent of all families studied were thought to have satisfactory food supplies throughout the year; 30 percent appeared to have inadequate supplies, although the average amount of money spent for food was not very different among the families rated as having good, fair, and poor food supplies.

Housing surveys were made by the Maine station in the summer of 1945 to determine the conditions of farm homes following the war years and the plans the families had made to improve their housing. The results of the survey showed that 48 percent of the houses needed painting, 32 percent needed porches repaired, and 41 percent needed walls and ceilings refinished. These were major items from the standpoint of occurrence, but other exterior and interior repair needs were also listed.

A study of kitchen arrangements in farmhouses was made at the Illinois station to determine the types of activities carried on, the kinds of equipment used, and the suitability of the rooms for the activities. Fourteen distinct types of activity were found, including dining, resting, laundering, playing, dressing, preparation of produce for the market, bathing, in addition to the food preparation activities.

Based on population centers of 2,500 or less and individual housing units located in the open country, a study was made by the Pennsylvania station to investigate the adequacy of rural housing. When compared with that of other sections of the United States, Pennsylvania housing ranked favorably, having a higher proportion of rural homes equipped with running water, bathrooms, gas, and electrical appliances, although with a higher percentage of old houses in need of repair.

Rural housing conditions in southwestern and southeastern Oklahoma are described in a bulletin by the Oklahoma station. Wide differences were found to exist among owners and tenants, and almost without exception, housing of farm owners as a group rated higher than those of tenants on all items studied.

More than one-third of the New York farmhouses were built before the Civil War according to a report from the New York (Cornell) station. Information on these housing conditions was obtained from a survey made in Cortland County, N. Y., to determine the amount of postwar building planned, and the amount of remodeling, repairing, or improvements to be done. Members of the Rural Housing Research staff are compiling a set of basic house plans, for new houses and remodeling of old, which will present ideas and suggest ways of meeting building problems.

Household equipment studies have been reported by the Nebraska, Wyoming, and New Jersey stations regarding pressure cooker gauge testers. At the Nebraska station, workers have suggested materials and directions for constructing and assembling testers which check the gauge while it is still fastened to the lid.

The effects of the heights of ironing board surfaces on the homemaker have been studied at the New York (Cornell) station. The subjects used in the study were given the opportunity to try different heights for ironing, and in analyzing results of the physiological responses of the study, it was found that they selected a height at which their responses were most favorable.

A survey was made by the Illinois station to study laundering facilities and practices of rural homemakers. Many of the women interviewed considered the household laundry to be their most tiring task, and a review of the details of the study show that a lack of sorting and storing and washing and drying facilities caused an increase in the natural fatigue of the homemakers. Practical suggestions in-

volving inexpensive, easily constructed or installed equipment or facilities were offered by the workers as a means of reducing the number of movements in washing.

ECONOMIC AND SOCIAL PROGRESS

Progress reports of station work on farm organization problems and problems of rural life tend to reflect the changes that must be made in passing from war to peace. During the early months of the war balanced production was an important objective, but as the war progressed, the demand for food became so urgent as to make necessary all-out production even at the expense of soil conservation and sound farm economy.

Now, farm organization is being influenced progressively more and more by considerations of efficiency and economy in the use of all the factors of production—land, labor, and farm machinery and equipment. Economic research, for example, points to the wisdom of soil-building practices which enrich the soil and improve the structure and texture. Experimental, as well as practical, results with green manures, lime, and commercial fertilizers are now being appreciated as never before. As the emergency passes, the production of proportionately less row crops and more legume-grass meadows for hay and grazing is emphasized. Hybrid vigor is employed to increase yields and lower costs of producing both crop and livestock products. Financial success in the dairy business, for example, is associated with keeping moderately large herds per man-year and better-than-average producing cows. Increasingly, cropping systems are based upon such research-created crops as hybrid corn, disease-resistant alfalfa and clovers, and adapted strains of brome grass. Other findings indicate the urgency of improving hay- and silage-making facilities and practices and lessening their costs. Still other economic studies point to easier ways to do the farm work so that chores and routine may prove less burdensome and time-consuming.

In harmony with the foregoing, economic research, as well as technical, is leading towards simpler but nonetheless adequate rations for livestock and poultry, particularly for dairy cattle and hogs. These simplified rations possess all needed nutrients and with the exception of some commercialized products may be produced on the farm. Other research points to needed improvements in farm machinery and implements, the improvement of farm structures, and better devices for passing title to farms from one generation to another without disrupting farm organization and productive capacity.

Rural life studies point to the need for better health and medical facilities and services in rural districts, to better schools, and to better levels of rural living than have prevailed thus far. Such research is not only helpful to farmers directly but also to technical scientists in the physical and biological fields, who find more immediate application of their discoveries and inventions in such matters as home construction, household management, and family nutrition.

The examples of results which follow, considered in connection with the technical items, should serve as illustrations.

WAR AND POSTWAR ADJUSTMENTS

The Alabama station cooperated with the Department in the analysis of data at State and Federal levels essential to projecting pro-

duction in Alabama a year ahead—for 1946. On the basis of estimates of national needs, and of the State committee's knowledge of the State's local situation, suggestions were made for 1946 crop acreages, yields per acre, numbers of livestock of various classes, livestock production, and desirable practices. The plans proposed were about the same as the realized production in 1944 and the official estimates for 1945 on acreages for cotton, corn, oats, and hay. Increases in acreage and production of principal vegetables and potatoes and sweetpotatoes and peanuts were suggested. Similar cooperative studies were carried on in most of the States.

As an example of the cooperative effort in studies leading up to needed adjustments, the Kansas station and the Department made a careful analysis of prospective demands for farm products and farm production resources of Kansas, which led to the following conclusions: That about 14.3 million acres of wheat would be seeded in the fall of 1946. On the basis of this wheat acreage, but allowing for normal wheat acreage abandonment, it was recommended that the acreages of feed crops—corn, sorghum, oats, and barley—be increased in 1947 by 21 percent more than was planted in 1945; that the acreage of tame hay and rotation pastures be increased by 6 percent over 1946; that the acreage of summer fallow be increased by 28 percent over 1946; no further increase in the acreage of cropland; moderate decreases in all classes of livestock except sows farrowed and chickens raised; increases in farrowings in the spring of 1947 of 8 percent and in fall farrowings of 27 percent over the 1946 numbers; and an increase of 10 percent in the number of chickens raised in 1947 over 1946. Other recommendations included a 10 percent increase in potatoes and a 4 percent increase in flax. A slight decrease in the soybean acreage was recommended. These recommendations are designed to prove helpful in developing the production aspects of outlook work, in the determination of production goals, and as a guide in the formulation of action programs.

In a study of the ability of Ohio farmers to meet wartime production needs, it was found that increased crop production could best be attained by increasing the yield per acre, that the acreage of soybeans should not be increased, and that the acreage of sod crops should be increased. The results of this study were used by the Department in setting up the 1946 crop and livestock goals for Ohio. The results are also being used as a basis for A. A. A. practice payments.

Production adjustment studies at the Alabama station, in cooperation with the Department, revealed that considerable increase in acreages of alfalfa, sericea, and kudzu would be profitable in Alabama on the basis of present conditions. Without control, some increase in cotton acreage could be expected to be profitable, while with cotton control, peanuts and tobacco would be first major crop alternatives if not likewise under quotas. With mechanization, efficient farming would call for considerable increase in cropland per farm family.

Research conducted by the Louisiana station and the Department indicated that on the average size of farms of 135.5 acres of cropland, average machinery inventories were \$2,365, with 78 percent for tractors and tractor equipment and 22 percent in mule-drawn equipment. The average cost of operating all tractors in 1944 was

\$4.22 per 10-hour day; one-plow tractors \$3.88, two-plow tractors of less than 17 drawbar horsepower \$4.05, and two-plow tractors of more than 17 horsepower \$4.87. The average cost of mule work per hour was 22 cents in 1944. On an average three mules were displaced by every tractor, but mule numbers have not been reduced to a minimum and over-all power costs can be lowered still further with mechanization. Production costs were reduced through the use of tractors, and returns to labor were greater when farming operations were mechanized. The amount of man-labor for the different crops was reduced substantially when tractors displaced mules. Reductions ranged from 25 to 60 percent depending upon the crop and the extent of mechanization.

In a study of adjustments in farming from the standpoint of production planning and soil conservation, the Missouri station estimates that the total supporting capacity of pasture crops for the 1945 year will exceed the livestock needs by approximately 6 percent. The condition for 1946 as estimated and assuming a normal pasture season would exceed livestock requirements by some 17 or 18 percent. These calculations are unusually significant in light of the rather serious shortage of both feed grains and cured roughages on farms in the State. Grain crops in Missouri for the 1945 season were much below normal and still further below immediately preceding years in production. The corn crop, which is the major feed crop, was already about two-thirds of a normal crop considering both volume and quality. Missouri farmers have been buying corn from Iowa, Nebraska, and other adjacent areas to try to make up the shortage.

A study of hog-feed ratios conducted by the Alabama station and the Department showed that the State's hog-corn ratio is consistently below the Corn Belt ratio primarily because of the higher price reported for Alabama corn. Yet, commercial hog production has persisted even at low ratios, supposedly unfavorable to hog production. Available evidence points to the conclusion that the reported corn price is too high for use as a cue to hog production since it largely reflects the quality of corn sold for food purposes and does not reflect the true value of the average quality of corn fed to hogs.

In a study of farm management factors affecting efficient food production, the Michigan station found that Michigan farmers normally keep more livestock than their grain production will support. Consequently, they have to depend upon importations from other States. While the grain supply on January 1, 1946, for the State as a whole, was slightly above normal, the lack of grain and protein feed shipments both from other States and within the State has made the situation critical on many farms. Feed-price ratios in Michigan during 1945 were about 10 percent above the 1931-40 average in the case of hogs, about average on dairy products, eggs, and steers, and 10 percent below for lambs. Farmers in this State continued their heavy production with a reduced labor supply. The production adjustment report for 1946 for Michigan was the basis for arriving at recommended crop acreages and livestock numbers and production for 1946.

The Colorado station and Federal and other State agencies prepared a report dealing with Colorado agricultural production adjustments. Analysis of cattle and sheep operator records showed a continually rising cost per unit in the operation of both cattle and sheep ranches.

The report to the War Food Administration was followed closely by Colorado agencies in establishing peacetime production goals for 1946. Results obtained from the analysis of cattle and sheep records have been helpful for consultation purposes and in making reports to farm and other agencies in regard to Colorado conditions.

In a study of wartime shifts in farm organization, the Iowa station completed a study of agricultural capacity for 1946, which was a continuation of those made by the Iowa and other stations, starting with 1942. Completed also was a study of adjustments in farm size. In the wartime capacity study suggested levels of crop and livestock production were established. The study of farm size adjustment indicated that the number of farm consolidations in Iowa has not been as great as commonly supposed. The greatest number of consolidations has taken place in the rougher, low-income sections. The trend which has taken place has been in the direction of larger farms and is associated as much with income and soil productivity as with mechanization.

In a study of types of farming, the Pennsylvania station found that livestock enterprises predominate over crop enterprises. Dairying is the major source of farm income. Corn, oats, wheat, and hay accounted for nearly 86 percent of the acreage of all crops harvested in the State. This study helps farmers adjust their production programs to the types of farming found to be the most profitable in their areas.

The Illinois station, in a study of cooperation in conservation programs, reported that conservation farming is steadily becoming more profitable. Production and earnings are steadily increasing on conservation farms and comparatively are steadily decreasing on nonconservation farms. Twenty McLean County conservation farms had 10 percent higher crop yields and \$7.89 more net income per acre than 20 otherwise comparable nonconservation farms in 1944, although about equal in yields and net incomes in 1935-36. Production adjustment studies show that, for a sound long-time land-use program for Illinois, acreage of intertilled crops should be reduced 20 percent and grasses and legumes on tillable land should be increased 50 percent compared with present use. The following of a complete conservation plan, in addition to conserving soil and water resources, returned in 1944, \$589 above the nonconservation system of farming on the equivalent of a 160-acre farm in McLean County, \$720 in Madison and St. Clair Counties, and \$892 in Stephenson, Jo Daviess, and Winnebago Counties.

The sweetpotato in north Louisiana was a relatively profitable crop in 1943, returning 47 cents per hour of man labor and bringing higher returns over all expenses per acre and per hour of man labor than cotton, peanuts, or corn. Under long-time average conditions, sweetpotatoes are in a strong competitive position when compared with cotton, peanuts, and corn. This study by the Louisiana station fills an important need in the consideration of alternative enterprises as possible replacements for cotton in the upland regions of Louisiana and neighboring States.

In an economic study of farm equipment, the Kentucky station found that about 80 acres of cropland per farm per year were necessary to make economical use of the tractor. Depreciation and repairs were the major items of expense of farm implements. Increased

annual use reduced depreciation and other overhead expenses such as interest, taxes, insurance, and housing. One-plow tractor costs averaged \$3.91 per day, two-plow tractor costs averaged \$4.33 per day, combine-harvester costs averaged 71 cents per acre, and corn picker costs averaged 54 cents per acre. Lower costs for farm machinery in Kentucky were obtained by greater annual use.

IMPROVING MARKETING

A warehouse and 10 retail stores of a well-known chain grocery company in Columbus, Ohio, were used as pilot plants by the Ohio station to measure wastes in distribution and explore the possibilities of prepackaging of fresh fruits and vegetables in sealed, transparent consumer units, refrigerated and unrefrigerated. The commercial possibilities and consumer acceptance of vine-ripened strawberries from Tennessee and tree-ripened peaches from South Carolina and Ohio were tested. Marketing tests were also made with local vegetables. By use of sealed units and refrigeration, "shelf life" of most perishables has been lengthened significantly. Consumers expressed strong preference for prepackaged, refrigerated self service over conventional bulk offerings. Wastes have been reduced. Savings have almost equaled extra costs, despite no advance in retail price. Sales have increased.

The Michigan station made a study of changes in form in which dairy products are sold from farms, i. e., in whole milk, cream, or farm butter. Inventory of plant capacity was made. An attempt was made to point out the direction the postwar readjustments would take. Work was begun on the bottling of evaporated nonsterilized milk for fluid distribution in paper bottles. Conclusions were: Reduction in output of butter in Michigan is just about offset by increase in fluid milk sales. Evaporated and condensed milk production in Michigan seems likely to decrease. Sale of farm separated cream will not return to its prewar level. In general it now appears technically possible to bottle and sell evaporated nonsterilized milk. Savings to consumers will probably average 3 cents per quart below present doorstep prices.

The Illinois station reports that increased demands for products made of whole milk, resulting from military and lend-lease needs, and for bottled milk and cream, arising from high consumer income, caused a marked diversion from sales of cream to sales of whole milk; 34 percent more whole milk was sold in 1944 than in 1939. Only 10 of 102 counties did not show an increase in whole milk sales; percentage increases in whole milk sales were smallest in the old established fluid milksheds, and in southern counties with few whole milk outlets. Declines on a density of sales basis were greatest in northwestern Illinois and in a broad belt across the center of the State where a marked increase in cheese production occurred.

Indices of prices of farm products in Pennsylvania and costs of certain things which farmers buy are being kept up to date by the Pennsylvania station. These indices are available for public use and were used during the past year in testimony at hearings held by the Pennsylvania Milk Control Commission and the Dairy and Poultry Branch of the War Food Administration.

Analysis of data obtained in a study of milk marketing by the Ohio station showed that under State control the following gains were

made: More accurate classification of milk as to use, substantial reduction in dealer discounts and other forms of price cutting, participation in the market control plan by all dealers and producers in the market and general stabilization of the price level at producer and distributing levels. Under Federal market orders from 1938 to date, the following improvements resulted: Standard practices in weighing, sampling, testing, and auditing have been established; producers' association functions have become more clearly defined; all dealers pay the same price for milk in various uses; and the market administrator's office has become a clearing house.

Follow-up by the New Hampshire station of the operation of milk trucking in the Colebrook milkshed, which has been reorganized during the war period according to findings of station research, showed all routes operating satisfactorily in 1945. Due largely to the every-other-day delivery system, the output per delivery man was 30 percent greater in 1945 than in 1941. Consumers were mildly indifferent to continuation of this system, but more than half expressed a preference for daily delivery when asked for an opinion.

Gross inequalities in freight rates on various vegetable crops from shipping points in New Mexico to eastern markets as compared with other competitive producing areas were revealed by studies at the New Mexico station. As a result of these findings, freight rates for several vegetables already have been reduced from Las Cruces and Roswell, N. Mex., to eastern markets, and further adjustments to equalize the competitive position of New Mexico growers with those in other areas are being sought.

The Connecticut (Storrs) station studied the preferences of about 600 consumers as to methods of delivering milk. In general, they are well satisfied with alternate-day delivery. Less than 20 percent would be willing to pay an extra cent per quart for daily delivery. Nearly 50 percent would be willing to give up the present system and have their milk delivered under a zoned or a public utility system at a saving of 1 cent or less, but 40 percent would be reluctant to accept any such plans even for savings of 5 cents or more.

Supplies of milk in most eastern markets have been unusually short during recent fall seasons, especially in 1943. Supplies have been unusually abundant during spring months, especially in 1945. This suggests that producers have shifted their production so as to produce relatively more milk in the spring and relatively less in the fall. Study of this situation in the Pittsburgh market by the Pennsylvania station indicates that no trend toward more or less uniform seasonal production of milk has occurred during the past 9 years; that fall shortages have resulted primarily from a greater increase in milk consumption than in milk production and partly from an actual decline in milk production from about the middle of 1942 to the middle of 1944; and that a marked shift toward less seasonal variation in prices to producers has occurred. This shift has been offset in part by seasonal adjustments in dairy production subsidy payments.

In a market price study, the Tennessee station found that 20 cotton improvement groups were approved, composed of 23,932 farmers, representing 382,871 acres. Twenty-three county-wide organizations were formed, with 223 gins acting as sampling agencies for the farmer groups. Thirty-nine gins cooperated in grade and staple determination. Total loss to cotton producers of Tennessee in 1945 due to rough

preparation is estimated as \$550,000 and in 1944, \$320,000. 1945 was a wet season, showing opportunity for improvement. Cotton farmers have been using data in making improvements in the quality of cotton, and in adopting better marketing practices. More farmers are having cotton classed; more are taking advantage of the government loan and purchase program; and more are securing highest available price on the open market. By properly handling the cotton before it is taken to the gin, farmers can greatly reduce the loss due to rough preparation.

A study of where Utah farm products are marketed shows a definite trend toward shipping to west coast markets rather than east, according to the Utah station. While agricultural production has increased in California it has not kept pace with the population increase, thus opening up opportunities for Utah to market her surplus farm products on the California market which is much closer than the eastern markets, and consequently these products can be moved there at much less cost with less spoilage. Such products as meat animals, most livestock products, feed grains, late potatoes, and canning vegetables, except tomatoes, are not produced in sufficient quantities in California to meet the market needs. Because of the differences in the time of maturity of certain crops and other factors that give rise to trade, California also imports considerable quantities of certain products that it also exports. These opportunities can be developed more fully by Utah producers by better grading, packing, and selling methods.

Detailed information on the amount of labor and the cost of equipment used to harvest hay in 1944 was obtained from 51 farmers in Livingston County and from 38 farmers in Cortland County in September and October 1944 by the New York (Cornell) station. With a horse-drawn mower about $1\frac{1}{4}$ hours were required to cut an acre of hay, as compared with slightly more than half an hour with a tractor-drawn mower. The cost of cutting an acre of hay was \$1.70 an acre with a horse-drawn mower, and 85 cents with a tractor-drawn mower. Although there was some variation, about 42 minutes were required to rake an acre of hay with a side-delivery rake drawn by a team, and 30 minutes when the rake was drawn by a tractor. Total cost for labor, power, and use of the rake was about \$1.05 an acre when the rake was drawn with a team, as compared with about 75 cents when a tractor was used. The total cost for labor, power, and equipment for moving hay from the windrow to the mow with loaders and wagons averaged \$3.69 a ton in Livingston County, as compared with \$2.56 a ton for loaders and trucks in the same county, and \$2.41 a ton for loaders and wagons in Cortland County.

Cost of producing milk in the southeastern Louisiana dairy area, the Louisiana station found, was more than twice as high in 1946 as in 1938, and increased about 16 percent from 1944 to February 1946. Major factors causing this increase in costs were the higher prices paid for dairy feeds, forced substitution of inferior feeds for kinds of feed usually purchased, and higher costs for farm labor. Part of the increased costs were offset by higher prices for milk and the feed subsidy payment. The results have provided a basis for establishing prices that Louisiana producers receive for milk under the Federal-State milk marketing agreement and for determining the subsidy rate paid for milk in the area. After the 1944 results were released, an increase

in price of about 25 cents per 100 pounds was made, effective early in 1945, which meant an increase of about \$400,000 to Louisiana farmers in the region and a stimulation which resulted in milk production in the area being increased over 1944.

The Louisiana station found that the total costs of producing sugarcane on large plantations varied from \$4.59 per ton in 1941 to \$5.93 per ton in 1944; receipts increased from \$4.21 per ton to \$6.58 during the same period. The results were used by the industry in comparing costs and returns for the purpose of improving efficiency and also by various Federal agencies as a basis for establishing administrative regulations.

The Louisiana station also found that the cost of growing, harvesting, and marketing a ton of cane on the family-type farms studied, not including a charge for the value of the operators' labor, averaged \$3.78 per ton in 1938, \$5.05 in 1940, \$4.38 in 1942, \$4.69 in 1943, and \$6.14 in 1944. The rapid increase in costs from 1943 to 1944 was due to higher costs for input items, mostly hired labor and machinery, and to lower than average yields in 1944. These farmers incurred a loss of about 8 cents per hour of man labor in 1938 and 1940, earned about 40 cents per hour in 1942 and 1943, and made about 10 cents per hour in 1944. Wide use was made of the results by the sugar industry, administrators of the Sugar Act, and farmers. Results of 1943 and 1944 were used in establishing the current subsidy rate paid to farmers for producing sugarcane and in establishing the minimum wage rates paid by farmers for hired labor. The most recent increase in the subsidy rate, about 50 cents per ton for the 1946 crop over the 1945 rate, represents a total increase in income to Louisiana sugarcane farmers of about \$2,000,000.

The Mississippi station found that cotton cost more to produce as soil fertility decreased, and crop costs were least on farms with good soil-crop adaptation. Dairy and cotton farms produced milk and cotton at the lowest costs and gave the highest returns per man hour.

In a study of cotton marketing, the Louisiana station found that the average margins per ton retained by ginnermen varied from -69 cents to \$8.40. Causes of the wide variations were use of arbitrary methods in arriving at weights of cottonseed, variations in methods used in making seed settlements with growers, charging low prices for ginning services and taking wide margins on cottonseed, and the degree of competition among gins. Gin price margins could be reduced by adoption of more uniform practices by ginnermen. Operations of a cooperative oil mill in Louisiana during the 1943-44 season indicate that cooperative processing provides an opportunity for reducing the spread between the price received by farmers and the value of cottonseed products. Parish-wide cotton improvement groups increased from 11 during 1942 to 23 during 1945. The acreage of one-variety cotton increased from 277,567 in 1944 to 389,184 in 1945.

Striking differences in the profitableness of various farm enterprises were revealed in a series of cost-of-production studies by the Puerto Rico University station. For example, average corn crops showed an average net return of only \$4.25 per acre in 1945, whereas the production of plantains, an important food crop, gave a net return of \$112 per acre. The production of tannias, another food crop, gave a net return of \$46 per acre, while under a careful system of intercropping

plantains and taniais, net returns of \$204 per acre were obtained. These figures exemplify the type of information being obtained from numerous farm enterprises which are proving very helpful in developing more effective use of land and labor on the Island.

LAND ECONOMIC STUDIES

The Kentucky station concluded that the analysis of the farms included in this study, applied to the crop year 1944, showed that the net cash farm income averaged \$5,386. The gross cash income per tillable acre averaged \$54.90 on these same farms and the cash operating expenses average \$27.57, leaving a net cash income per tillable acre of \$27.33. The data were also used in the preparation of the report furnished by the Kentucky station to the Department on capacity of agriculture.

The Oregon station reports that developing methods of utilizing logged-off lands gives promise of producing large volumes of grass and forage for livestock, hitherto not available. It relieves the counties to which most of the logged-off lands have reverted for taxes from paying fire control assessments, inasmuch as the lands that can be used for livestock grazing have increased in value and are being taken into private ownership by stockmen. Thus, a public burden is relieved, wealth is increased, and fire hazards are reduced.

A study of the farm and forest resources in the Appalachian region highlands of Kentucky, made by the Kentucky station, dealt with the natural and human resources of the eastern Kentucky Appalachian highlands area. Because the study area exemplifies the kind of economic and social quandary faced by many southern Appalachian people in making a living from their land resources, this study was pertinent to a wide region as are also the principles developed by the study. The dense rural population depends entirely upon part-time subsistence farming for a living, yet the only prime farming land lies in the narrow ribbons of bottom land bordering the streams between the deep, sharp-ridged hills, and amounts to less than one-twentieth of the whole land area. The farm communities clustered along these bottom land ribbons and pushing up the hillsides are the sixth-generation descendants of the first frontier settlements. Cash incomes are low and are derived almost entirely from part-time employment off the farms, from public allotments of various sorts and on a small scale, and irregularly from sales of timber and work in the woods. Mining, a mainstay of many Appalachian communities, is relatively undeveloped. This is true also of industry. Only the forests which occupy seven-tenths of the land support any industry and this is a mere scattering of small sawmills and other small wood-working plants. Cut over in large scale operations 20 to 50 years ago, the timber resource today is only beginning to grow back, and much of it is still sparse and of low quality.

In a study of inheritance and transfer of farms from one generation to the next made by the Michigan station, it appears that contracts are the best arrangement for transferring farm property from one generation to the next. The interests of the son, the parents, and the other children can usually be maximized by the use of a contract to transfer the farm property. A sales agreement, land contract, or future-interest contract can be used. Under the con-

tract the son has a secure and dependable arrangement whereby he can acquire ownership of the farm. The parents are able to use their life savings that they have invested in the land without violating their own security or the interests of the other children in the farm.

The Oklahoma station found that large areas of privately owned grassland in north central and northeastern Oklahoma are leased each year for the grazing of beef cattle. An analysis of pasture leasing systems revealed that the most prevalent practices are the renting of land at a given rate per acre or at a given rate per 100 pounds of gain, both of which encourage the renter to stock pasture at a heavy rate which leads to overgrazing and pasture depletion. Under an alternative plan recommended by the station in which the cattle owner would be charged a given rate of rent per steer grazed, the financial advantage to the renter will be to graze more moderately, thus encouraging pasture conservation. The station is continuing work on this problem with particular attention to the rate of land depreciation due to physical overgrazing.

In a study of land tenure, the Mississippi station found that white sharecroppers are younger than Negro sharecroppers and progress out of the sharecropper class at an earlier age. They also move oftener than Negroes. A good many Negroes in this area have become owners, although for the most part they have bought small farms on poor land. The average income for white or Negro owners on small farms is lower than for white or Negro sharecroppers, respectively, on farms of like size. Sharecroppers, both white and Negro, have better land and equipment than owners on small farms. The station concludes that all programs designed to improve tenure conditions in the area should be examined carefully to make sure that change from sharecroppers to owners does not result in a reduction rather than an increase in income.

Results from the Arizona station show that during the year 1945, irrigated lands with good water rights increased in sale price about \$25 an acre. Land prices at the beginning of 1946 had once more established their normal relationship with the sale prices of crops. Thus one more year was added to the continuous land-price rises from the year 1939.

Farm real estate values in Pennsylvania have increased during World War II at about the same rate as during a comparable period in World War I. Unless farm prices are maintained at a fairly high level, some purchasers will have difficulty in paying for land at prevailing real estate values, the Pennsylvania station reports.

In a study of Ohio farm land values it was found that the price trends of farm real estate during World War II parallel those of World War I but on a lower level. A continuance of the present trend, June 1946, however, will put farm land prices on the highest level in history before the end of 1948. Farm mortgage credit has remained on a relatively conservative basis during World War II and a disastrous period of foreclosures may be avoided. About one-half of all purchases have been made free of all mortgage debt. Some tendency has prevailed to bid up the price of poor land faster than the price of good land. The net flow of farms is into the hands of persons who are, or intend to be, owner operators.

TAXATION

A study by the Wyoming station of the property tax situation during the war years has revealed a significant trend of some concern to the people. During this period property values and labor costs were undergoing inflation but there was no increase in the State or local property taxes. This necessarily resulted in definite reduction in the extent of services performed by State and local governments for the people. At the same time Federal income taxes increased from a small percentage of the amount of the general property taxes to about double that amount. As a consequence, many of the services to the public had been shifted from State agencies that could not meet rising costs to Federal agencies that could.

In a study of the causes of tax delinquency, the Texas station found that "unknown owner" for the most part reflects a lack of system and inadequate practices of tax administration. In amounts, "unknown owner" contributed about 16 percent of total delinquent State taxes and about 12 percent of county taxes for the year 1943. This cause is of more importance than this figure indicates, however, since most of the "unknown owner" delinquency is found in the rural counties where valuations are not large. Forty-six counties had their entire delinquent rolls of "unknown owners." About 40 percent of all amounts of delinquency is from the rendered rolls and about 60 percent is from the unrendered rolls. For 1944 there was a slight increase in the average tax per acre of farm and ranch land, the increase being from 16.6 to 17.3 cents per acre. Indications are that for 1945 there will be another slight increase. The tax trend data have served as basic information to the station and to county and State officials.

FARM INCOME

In 1945-46, as in previous years, financial and production data were secured from a group of operators in the northern Colorado irrigated area and also from a group of farm operators in the northeastern Colorado dry-land area by the Colorado station. In connection with the irrigated area, winter feed lot operating costs were likewise secured for a group of both sheep and cattle feed lots. Farm operators in the irrigated area made smaller net incomes in 1945 than in either of the 2 previous years, due largely to increased operating expenses. Cash operating expenses per acre of cropland on irrigated farms was two and one-half times as high in 1945 as in 1940. Net incomes on dry farms in 1945 were about 60 percent better than in 1944, but they were still 10 percent below the 1943 level. Changes in crop yields appear to be the biggest cause for difference in income on the dry-land farms. Data secured in connection with this study have been used in the preparation of reports to the War Food Administration. They have also served as a basis for estimates used in advising farmers and farm groups and in making economic reports to various agencies.

Cash income studies by the Arizona station showed that cash received by Arizona agriculturists for crops sold off the farm and range in 1945 reached an all-time high of 134 million dollars. This represented a 10-million-dollar increase over 1944, and was largely because of increased returns from truck crops. A part of this increase was the result of larger production of carrots and cantaloups, and the remainder should be attributed to increased prices.

WORK SIMPLIFICATION AND FARM LABOR

A study made by the Kentucky station resulted in the discovery of principles and methods underlying the doing of farm jobs so as to obtain maximum accomplishment for the limited labor forces on farms, and in throwing light on ways by which unnecessary work might be eliminated, easier and better methods and sequence in performing work, more economical and convenient kinds and combinations of equipment and crews, and improved methods, techniques, and standards of accomplishment. Especially noteworthy results were obtained in economies in the operations of suckering, cutting, housing, and stripping tobacco and in pulling and setting tobacco plants in the field. Improved techniques and equipment devised for pulling tobacco plants enabled tobacco growers who used the new ideas to reduce the time used in pulling plants for setting an acre of tobacco from an average of 15 to 5 hours. In the priming of tobacco the use of improved methods saved approximately 22 man-hours per acre. The average value of the tobacco from primed plants was \$131 greater per acre than that from unprimed plants.

Studies by the Rhode Island station of the time requirement for harvesting hay show that the one-man baler, or the buck rake and power fork on short hauls, require less than one-half the man-hours per ton as when hay is loaded by hand and unloaded by the power fork. The station found that either method requires less hand labor than the hay loader and power fork.

From detailed studies of time spent on various chores connected with diary farming, the Minnesota station has been able to give information to farmers on methods of doing various operations, so that marked saving of time has been accomplished. The savings are illustrated by the results on one farm where time spent on doing chores was reduced from 3 hours 39 minutes per day to 2 hours 45 minutes. The farm under study was already using more efficient methods than the average neighboring farms in doing the daily chore work. With a crew of 10 to 12 men and 3 to 4 wagons, from 2 to 4 man-hours were required per ton of corn silage harvested where bundles were picked up in the field by hand and loaded on the wagon. The average was 2.1 man-hours per ton, 5.2 tons per hour, and 21 hours to fill a 100-ton silo. On farms using a bundle loader with a crew of 5 to 9 men and 3 to 4 wagons, about 0.8 man-hour was required per ton of silage, with 8.3 tons being handled per hour, and 12 hours to fill a 100-ton silo. On farms where an ensilage harvester was used, a crew of 4 to 6 men with 3 dump trucks or 3 large trucks from which the corn silage was pitched into the blower, about 0.6 man-hours was required per ton, with 8.5 tons handled per hour, and 12 hours to fill a 100-ton silo.

Utah station studies on the labor requirements for agricultural production in Utah have made available to farmers and labor administrators in the State the amount of labor required for each county, for each crop, and for each kind of livestock. The study showed that there were about 400,000 man-months of labor needed, and that of this amount 75,000 man-months were not available in the areas needed, but had to be imported.

Hay harvesting studies by the Maine station showed that the labor used in baling, loading, and storing a ton of hay averaged 109 minutes

with a buck rake, 109 minutes with a one-man baler, 157 minutes with a three-man baler, 166 minutes with a hay loader, and 222 minutes when pitched on by hand. A tractor with a 7-foot bar mowed an acre of hay in 25 less minutes than a two-horse team with a 6-foot bar. Wide use was made of the information as a guide to farmers in choosing more efficient equipment.

Since farm wages are approximately three times their prewar level at the present time, August 1946, the New York (Cornell) station reports, in doing daily chores on 20 dairy farms in New York, studies of work methods reveal great opportunities for increasing production per worker, and reducing production costs, through the adoption of better methods, equipment, and building arrangements on many farms. On one of the farms studied, two extra hours a day during the winter months—the equivalent of 6 weeks of extra time—were spent in taking care of a herd of 20 cows, as compared with another farm on which the work had been more carefully planned. Furthermore the farmer who planned his work carefully saved more than 700 miles of walking. The arrangement of buildings, kind and arrangement of equipment used, and organization of the work accounted for most of these differences.

A special field survey was made by the Louisiana station in the rice area in March to June 1945, to determine the seasonal demands for labor, the supply of labor available by types and months, and the number of kinds of additional labor which would be needed to grow and harvest the 1945 rice crop. The supply of labor on 147 rice farms surveyed in 1945 varied from 1.89 men per farm in January to 2.26 in April, 2.0 in July, and 2.99 in October. The labor required on these same farms varied from 1.81 men per farm in January to 2.84 in April, 3.80 in July, and 12.36 in October. The supply of labor in comparison to need was 104 percent in January, 79 percent in April, 53 percent in July, and 24 percent in October.

POPULATION

A study of migration in Utah made by the Utah station shows that it is the better educated younger youth who are leaving the State for better opportunities elsewhere. Of the youth who stayed at home, 9.6 percent were in the professional and semiprofessional classes, while of those who left the State, 17.4 percent were in these classes. More individuals in the age groups 19, 20, and 21 left the State than any other age groups. These groups represented 35.6 percent of those migrating from the State. Since the 1910 census, net migration from Utah has increased steadily. In 1910 it was only 1,259; in 1940 it was 91,688. Of these numbers, the largest percentage is from the rural areas where opportunities for employment are fewer.

In a study of population trends, the Pennsylvania station found that the replacement index for the State was 93.6. An index of 100 means that the population was just reproducing itself. The replacement ratio for urban was 79, rural nonfarm 123, and for rural farm 139. The State has continued to lose population over the years to western and northern States. In the past three decades there has been a movement of population into the State from the South. A large proportion of this is colored, increasing the proportion of Penn-

sylvania's Negro population. The proportion of the population classified as rural nonfarm and rural farm has, of course, decreased over the years. The population is rapidly aging as a result of lower birth rates and migration out of the State of those in the younger age group.

COOPERATION

An inventory of the activities of cooperatives, recently completed by the Pennsylvania station, showed a majority of Pennsylvania farmers are patrons of one or more of these organizations. Farmers marketed or purchased through these cooperatives in 1943 more than 100 million dollars' worth of commodities. Approximately 60 percent of this volume of business came through marketing and 40 percent through purchasing.

A study of 14 cooperative cheese factories was undertaken by the Minnesota station on the invitation of the Minnesota Cheese Producers Association, whose member plants were confronting some difficult competitive problems. The results of this study were presented in a series of meetings with the combined boards of the 14 factories, the board of directors of the Cheese Producers Association, and the stockholders of each of the 14 factories. Since completion of the study, the plants have decided to consolidate into one plant and most of the individual plants are being closed. It is expected that important economies will result from this change which will benefit the dairy farmers of the area.

RURAL NEEDS

Anticipating postwar needs, the Kentucky station brought together basic information upon which plans for improving postwar agriculture and rural life might be predicated. The station concluded that about 4 percent of the total farm population lives in Kentucky but receives only about 2 percent of the gross income to agriculture in the United States. However, Kentucky farmers appear to be improving their relative position. They also use in their homes a larger proportion of their production than do farmers in the rest of the country. Emphasis has been shifting from crops to livestock as a source of income in the United States. The trend is similar but less marked in Kentucky agriculture. Improvement in feed-crop production doubtless has permitted the increase in livestock. In particular, the proportion of farm income in Kentucky coming from cattle and calves has increased during the past 20 years. Tobacco is the leader in bringing cash returns to Kentucky farmers. While the proportion of returns coming from tobacco fluctuates considerably from year to year, no pronounced trend is apparent in its relative importance.

As a result of a study made by the Ohio station, the rural health needs of the State have been clarified. They include more and better physicians, dentists, and other health workers; more and better hospitals and related facilities; more and better mental health services and facilities; more and better public health services and facilities; and easier ways of paying the costs of health and medical services and facilities.

In a study of the medical and health facilities available to the rural people of Louisiana, the station found that in 1945, after losses to the

armed forces, Louisiana had one doctor for each 1,464 people, which was slightly better than the minimum standard set by the Surgeon General of the United States for wartime medical care. However, with the distribution that existed, the 9 most urban parishes had a ratio of one doctor for each 926 people, and the other 57 parishes had only one doctor for each 2,739 people. Eight parishes actually had more than 5,000 people for each physician, but half of these were adjacent to urban parishes with much better ratios. Forty-four parishes have at least one hospital or clinic containing 12 or more beds. Forty-seven have facilities for appendectomies, and in 50 parishes tonsillectomies are performed. Though ranking twenty-second in the Nation in ratio of general hospital beds to population, Louisiana still ranks well above all other Southern States. Local health units served 87.5 percent of the parishes in Louisiana.

From detailed studies of public school organization and support, the South Dakota station has made important contributions that are gradually evolving a new pattern of school districts and a wider tax base for school support under South Dakota conditions. Through the results revealed by the study, some 918 small common schools are now sending tuition pupils to 328 town schools. This is 80 percent of the town-centered individual schools of South Dakota. This past year, these 328 receiving schools served an average of 9.4 common school tuition pupils. Small enrollment and poorly financed high schools are following a similar trend toward closing and sending their remaining pupils to larger and more central schools. The station workers estimate that the closing of 128 small enrollment and inadequately financed schools will mean the sending of the remaining children to town schools as tuition pupils has meant a saving of at least \$500 per district on the schools closed during the year. This would mean a total saving of \$64,000 to the taxpayers of the districts.

In a study of rural housing, the Virginia station reported that close to 100,000 Virginia rural families have dwellings substandard in construction, condition, conveniences, or aesthetic qualities. Census data show that farm houses and home convenience standards are much below those of nonfarm rural and urban homes, and that tenant housing standards are much below those of owners. One white family in six and one in three of the Negroes live in houses with three rooms or less; while nearly one-third of the houses of the whites and two-fifths of those of the Negroes are reported as needing major repairs.

A survey of the probable requirements for agricultural machinery in Delaware for the years 1946 and 1947 by the Delaware station indicated that the purchase of about 4 million dollars worth of machinery and implements would be needed during these 2 years to bring inventories up to requirements.

In a study of the status of the frozen-food locker and the home-unit locker in Ohio, the Ohio station estimated that about half of the farmers, both those who now rent lockers and those who do not, are expecting to purchase home cold-storage units. Many who now rent lockers will discontinue, and some plants may experience difficulty in renting all their lockers. It is also apparent that locker plants cannot expect a very large percentage of patrons from distances more than

5 miles from their plants. The results of this study were used by those in the cold-storage locker business and by manufacturers of home units and supplies.

STATISTICS—PERSONNEL, PUBLICATIONS, INCOME, AND EXPENDITURES

PERSONNEL AND PUBLICATIONS

The research personnel of the experiment stations in 1946 included 2,189 staff members devoting full time to station research and 2,185 who divided time between research and teaching or extension work. The total in both categories, 4,374, represented an increase of only 4 over the total of 1945 but there were 26 more full-time workers in 1946.

Publications of the experiment stations in 1946 included 633 bulletins, circulars, and reports, 1,855 articles in scientific journals, and 640 miscellaneous publications. By comparison with 1945, the stations published 89 fewer bulletins, circulars, and reports, 114 more articles in scientific journals, and 183 more miscellaneous publications.

Data by individual States relating to personnel and publications are shown in table 1.

INCOME AND EXPENDITURES

Appropriations under the authorizations of the Hatch, Adams, and Purnell Acts for use by the experiment stations in 1946 totaled \$4,542,500, each State receiving \$90,000 and Alaska receiving \$42,500. A total of \$2,663,708 was appropriated under the Bankhead-Jones Act of June 29, 1935, with allotments to the individual States, Alaska, Hawaii, and Puerto Rico as shown in table 2. These allotments are made on the basis of rural population adjusted in accordance with the provisions of the Department of Agriculture Organic Act of 1944.

The total of Federal-grant research funds appropriated under all authorizations was \$7,206,208, an increase of \$205,000 over 1945.

Expenditures of Federal-grant funds are shown under object classes by individual experiment stations in tables 3, 4, 5, and 6, and expenditures of non-Federal funds in table 7. The 1946 expenditures of non-Federal funds which include State appropriations, research grants, and income from other sources totaled \$20,786,854 as compared with \$17,342,749 in 1945. The 1946 non-Federal fund expenditures by all of the stations approximated \$2.88 for each \$1 of Federal grants.

TABLE 1.—Organization, personnel, and publications of the experiment stations for the year ended June 30, 1946

Station	Date of legislative assent to Hatch Act	Date of organization under Hatch Act	Personnel					Publications					
			Full-time research	Research and teaching	Research and extension	Research teaching, and extension	Total research workers	Station publications		Articles in scientific journals		Miscellaneous publications	
			Number	Number	Number	Number	Number	Number	Pages	Number	Pages	Number	Pages
Alabama	Feb. 27, 1889	Apr. 1, 1888	36	26	2	1	65	3	58	13	87	14	149
Alaska	May 2, 1929	May 1, 1931	8	1	1		10	3	116				
Arizona	Mar. 19, 1889	July 1, 1889	17	27			44	17	514	13	60	2	5
Arkansas	Mar. 7, 1889	Apr. 2, 1888	12	29		1	42	7	181	3	6		
California	Mar. 12, 1889	Mar. 13, 1888	68	186			284	9	372	268	2,895	125	873
Colorado	Mar. 25, 1889	Feb. 20, 1888	29	49	1	5	84	8	202	22	44	65	195
Connecticut	May 18, 1887	May 18, 1887	55				55	12	901	43	328	7	12
State	do	Apr. 1, 1888	15	8	2	4	29			19	38		
Storrs	Apr. 14, 1887	Feb. 21, 1888	12	11	3	3	29	14	227	26	71		
Delaware													
Florida	June 7, 1887	Mar. 16, 1888	86	12	5	5	108	23	737	59	258	95	128
Georgia	Dec. 24, 1888	Feb. 18, 1888	48				48	11	331	14	87	7	17
Hawaii	Mar. 31, 1911	July 1, 1929	29	14			43	5	439	9	50	3	108
Idaho	Jan. 23, 1891	Feb. 26, 1892	15	21	2	5	43	11	163	13	105	6	42
Illinois	May 11, 1887	Mar. 21, 1888	46	84	6	3	139	8	306				
Indiana	Jan. 19, 1889	July 1, 1887	96	31	4	6	137	8	150				
Iowa	Mar. 1, 1888	Feb. 17, 1888	76	103	20	6	205	30	1,000	70	810	7	150
Kansas	Mar. 3, 1887	Feb. 8, 1888	37	89			126	13	360	65	(¹)	2	156
Kentucky	Feb. 20, 1888	Apr. 29, 1888	17		1	11	97	21	779	36	234		
Louisiana	July 12, 1888	Apr. 5, 1887	63	30			93	15	546				
Maine	Mar. 16, 1887	Feb. 16, 1888	29	10		2	41	8	505	4	12	2	30
Maryland	Mar. 6, 1888	Mar. 9, 1888	12	22	5	18	57	6	208	19	160	7	56
Massachusetts	Apr. 20, 1887	Mar. 2, 1888	59	18			77	10	328	23	136		
Michigan	Apr. 12, 1889	Feb. 26, 1888	67	80	6	7	160	10	678	50	313		
Minnesota	Feb. 4, 1889	Jan. 26, 1888	42	100	5	3	150	9	340	62	391	36	104
Mississippi	Jan. 31, 1888	Spring 1888	39	17		3	59	37	761	19	132	81	94
Missouri	June 11, 1889	Jan. 31, 1888	12	70		2	84	31	884				
Montana	Feb. 16, 1893	July 1, 1888	20	21		7	55	5	140	3	11	2	27
Nebraska	Mar. 31, 1887	June 14, 1887	29	38			69	13	459	16	16		
Nevada	Feb. 8, 1889	Dec. 1887	15	1	2		10	2	27				

New Hampshire	Aug. 4, 1887	Feb. 22, 1888	13	31	7	51	14	350	5	34	43	216
New Jersey	Mar. 16, 1887	Mar. 5, 1888	53	69	1	2	115	306	56	600	1	1
New Mexico	Feb. 28, 1889	Nov. 14, 1889	10	16	2	29	10	339	6	34	1	
New York:												
Cornell	Mar. 30, 1887	Apr. 30, 1888	35	133	17	186	15	842	397	1,830	4	72
State	(2)		66			66	10	314	40	40		24
North Carolina	Mar. 7, 1887	Dec. 5, 1889	69	40	9	119	5	332	13	86	3	7
North Dakota	Mar. 8, 1890	Oct. 15, 1890	29	19	1	49	11	349	349	51	7	17
Ohio	Mar. 16, 1887	Apr. 2, 1888	123			123	12	560	51	(1)		
Oklahoma	Oct. 27, 1890	Aug. 14, 1891	31	52		84	26	876	64	308		
Oregon	Feb. 25, 1889	July 2, 1888	55	43	6	104	32	505	40	60		
Pennsylvania	June 3, 1887	June 30, 1887		143		143	7	219	29	191	19	246
Puerto Rico	Aug. 16, 1933	Nov. 14, 1935	49			49	5	400	11	57	2	14
Rhode Island	Mar. 31, 1887	Nov. 3, 1888	16	9	5	31	2	108	3	16	4	39
South Carolina	Dec. 22, 1887	Jan. 1888	43	15	1	62	7	292				
South Dakota	Mar. 11, 1887	Nov. 17, 1887	20	15	1	36	8	115	4	6		
Tennessee	Mar. 29, 1887	July 24, 1887	55	14	4	73	27	1,047	10	61	2	8
Texas	Apr. 2, 1887	Jan. 25, 1888	142	1		143	9	449				
Utah	Mar. 8, 1888	Nov. 6, 1889	17	27	7	51	6	275	15	72		
Vermont	Nov. 8, 1888	Feb. 28, 1888	11	9	5	32	8	345	5	32		
Virginia	Feb. 29, 1888	June 13, 1888	57	8	5	71	27	353	24	130	2	62
Washington	Mar. 9, 1891	May 1, 1891	71	38		109	9	361	10	92		
West Virginia	Feb. 22, 1889	June 11, 1888	26	28	6	63	7	248	7	49	3	28
Wisconsin	(3)	July 1, 1887	41	74	14	132	7	357	187	250		
Wyoming	Jan. 10, 1891	Mar. 27, 1891	11	23		34	8	196	9	59	89	89
Total			2, 189	1, 912	186	4, 374	633	21, 430	1, 855	10, 251	640	2, 962

² First made eligible to receive part of the State allotment of Federal funds by legislative act approved May 12, 1894.

¹ Total pages unknown.

³ Session of 1887.

TABLE 2.—Income of the experiment stations for the year ended June 30, 1946

Station	Federal grants ¹			Non-Federal						Grand Total	
	Hatch, Adams, and Purnell ²	Bankhead-Jones	Total	State appropriations	Special endowments, industrial fellowships, etc.	Fees	Sales	Miscellaneous	Balance from previous year		Total
Alabama.....	\$90,000	\$89,423.98	\$179,423.98	\$353,460.00	\$49,410.15	-----	\$144,879.21	\$2,779.17	\$104,690.51	\$715,219.04	\$894,643.02
Alaska.....	42,500	2,440.15	44,940.15	-----	-----	-----	33,098.11	7,500.00	14,936.83	46,534.94	91,475.09
Arizona.....	90,000	14,392.26	104,392.26	129,780.51	-----	-----	24,715.41	-----	19,787.18	183,283.10	287,675.36
Arkansas.....	90,000	69,148.00	159,148.00	138,669.73	-----	-----	79,414.92	1,723.65	23,080.84	242,889.14	402,037.14
California.....	90,000	88,718.14	178,718.14	1,524,624.51	137,939.14	-----	129,468.61	-----	169,799.76	1,961,832.02	2,140,550.16
Colorado.....	90,000	24,243.47	114,243.47	155,281.30	22,276.06	-----	119,070.48	-----	86,260.17	385,193.66	499,437.13
Connecticut.....	45,000	12,191.48	57,191.48	196,639.98	15,550.00	-----	-----	-----	-----	212,189.98	269,381.46
State.....	45,000	12,191.47	57,191.47	67,638.47	6,983.89	-----	-----	-----	-----	74,622.36	131,813.83
Storrs.....	90,000	5,622.44	95,622.44	54,623.00	-----	-----	72,590.42	40,795.38	24,060.34	192,075.14	287,697.58
Delaware.....	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Florida.....	90,000	37,680.70	127,680.70	1,191,420.00	-----	-----	131,663.41	-----	97,829.80	1,420,913.21	1,548,593.91
Georgia.....	90,000	94,499.88	184,499.88	152,750.00	45,778.37	-----	73,624.25	-----	52,105.27	324,257.89	508,757.77
Hawaii.....	90,000	9,727.90	99,727.90	244,303.87	1,181.80	-----	30,099.89	-----	2,617.04	278,202.60	377,930.50
Idaho.....	90,000	15,404.82	105,404.82	27,580.46	-----	-----	56,010.39	-----	16,276.54	99,867.39	205,272.21
Illinois.....	90,000	93,841.72	183,841.72	513,347.74	81,906.82	-----	207,138.51	-----	802,393.07	986,234.79	1,172,471.58
Indiana.....	90,000	68,142.18	158,142.18	459,772.87	105,002.60	10,000.00	292,433.01	60,208.68	440,190.84	1,367,608.00	1,525,750.18
Iowa.....	90,000	69,803.53	159,803.53	352,007.97	99,992.39	-----	154,524.85	-----	180,619.66	787,144.87	946,948.40
Kansas.....	90,000	53,614.75	143,614.75	238,127.44	-----	-----	153,559.08	88,246.85	131,698.41	561,631.78	705,246.53
Kentucky.....	90,000	88,327.80	178,327.80	110,937.72	-----	177,703.07	57,700.00	-----	346,340.79	384,007.50	524,668.59
Louisiana.....	90,000	61,211.39	151,211.39	339,680.15	44,327.35	-----	-----	-----	-----	384,007.50	535,218.89
Maine.....	90,000	22,408.10	112,408.10	115,394.44	11,709.22	-----	41,013.54	27,356.66	30,104.23	225,668.09	338,076.19
Maryland.....	90,000	32,781.37	122,781.37	105,029.00	23,075.10	-----	64,821.86	670.28	38,988.87	232,885.11	355,366.48
Massachusetts.....	90,000	20,231.15	110,231.15	203,663.06	21,155.75	-----	-----	-----	26,191.20	251,040.01	361,271.16
Michigan.....	90,000	79,697.18	169,697.18	363,306.91	-----	-----	32,083.51	-----	393,892.42	565,089.60	767,569.96
Minnesota.....	90,000	62,041.49	152,041.49	418,877.64	68,294.64	3,664.40	124,691.79	-----	-----	615,528.47	767,569.96
Mississippi.....	90,000	78,610.71	168,610.71	212,500.00	14,200.00	-----	123,720.72	23,361.47	219,993.09	593,775.28	762,385.99
Missouri.....	90,000	83,175.72	173,175.72	107,594.58	10,986.78	64,873.50	66,173.51	-----	122,889.38	372,517.75	545,693.47
Montana.....	90,000	16,687.31	106,687.31	180,695.00	-----	-----	179,131.44	6,397.17	86,385.77	452,009.38	559,296.69
Nebraska.....	90,000	41,505.16	131,505.16	182,870.15	-----	-----	188,083.48	-----	-----	370,953.63	502,458.79
Nevada.....	90,000	2,962.52	92,962.52	2,962.52	-----	-----	17,036.87	-----	16,672.97	36,672.36	129,634.88

New Hampshire.....	90,000	9,216.35	99,216.35	9,216.36	---	6,506.65	---	29,094.37	44,817.38	144,093.73
New Jersey.....	90,000	33,865.35	123,865.35	455,773.36	---	---	---	---	685,245.75	809,111.10
New Mexico.....	90,000	15,725.69	103,725.69	63,500.00	---	---	---	74,023.38	180,035.90	285,761.59
New York.....	81,000	92,116.31	173,116.31	877,352.90	---	182,773.13	3,926.93	---	1,094,052.96	1,237,169.27
Cornell.....	9,000	10,233.14	19,233.14	486,040.27	---	18,139.26	---	---	504,175.53	523,414.67
State.....	90,000	114,926.05	204,926.05	283,186.81	---	47,199.03	18,778.29	18,319.01	367,483.14	572,409.19
North Carolina.....	90,000	26,411.59	116,411.59	105,439.26	---	50,435.98	---	35,947.55	262,601.17	379,012.76
North Dakota.....	90,000	101,527.46	191,527.46	828,896.74	---	139,019.66	---	414,404.59	1,373,848.45	1,573,545.45
Ohio.....	90,000	73,409.01	163,409.01	436,763.76	---	168,461.33	---	116,245.38	731,087.46	894,406.47
Oklahoma.....	90,000	24,689.53	114,689.53	288,680.91	---	106,509.17	---	---	548,574.79	663,264.32
Oregon.....	90,000	146,599.59	236,599.59	273,399.77	---	75,710.90	---	29,019.70	445,424.07	682,023.66
Pennsylvania.....	90,000	57,647.71	147,647.71	507,000.00	---	19,471.11	---	---	526,471.11	674,118.82
Puerto Rico.....	90,000	2,653.11	92,653.11	10,000.00	---	14,652.02	---	11,116.22	47,048.24	139,701.35
Rhode Island.....	90,000	64,344.59	154,344.59	230,000.00	---	307,500.47	---	143,282.99	680,783.46	835,128.05
South Carolina.....	90,000	26,082.74	116,082.74	54,500.00	---	60,456.57	---	43,152.54	162,353.27	278,436.01
South Dakota.....	90,000	83,564.08	173,564.08	105,502.64	---	99,900.42	---	---	205,403.06	378,967.14
Tennessee.....	90,000	161,288.81	251,288.81	546,875.00	---	486,138.35	87,248.60	401,895.62	1,539,281.19	1,790,570.00
Texas.....	90,000	11,336.91	101,336.91	134,746.32	---	44,552.00	---	29,024.28	219,835.60	321,172.51
Utah.....	90,000	11,274.80	101,274.80	18,500.00	---	4,759.77	3,900.00	4,083.69	31,843.46	133,118.26
Vermont.....	90,000	77,043.23	167,043.23	254,796.04	---	27,065.00	---	16,633.71	298,494.75	463,537.98
Virginia.....	90,000	36,025.87	126,025.87	404,434.15	---	100,641.75	---	---	531,191.18	657,217.05
Washington.....	90,000	60,514.12	150,514.12	73,000.00	---	108,580.13	---	30,725.96	212,305.09	362,820.21
West Virginia.....	90,000	65,188.75	155,188.75	642,991.00	---	179,400.00	---	---	1,093,855.00	1,249,043.75
Wisconsin.....	90,000	7,294.44	97,294.44	61,941.01	---	68,273.55	---	30,965.51	161,182.07	258,476.51
Wyoming.....	90,000	2,663,708.00	7,206,208.00	15,356,081.32	---	4,955,390.04	322,893.13	3,393,803.20	25,858,820.60	33,065,028.00
Total.....	4,542,500	2,663,708.00	7,206,208.00	15,356,081.32	---	4,955,390.04	322,893.13	3,393,803.20	25,858,820.60	33,065,028.00

¹ Includes unexpended balances from the previous year as follows:

Hatch—Connecticut Storrs, \$453.57; Illinois, \$938.93; New York Cornell, \$2.88.
 Adams—Delaware, \$105.02; Indiana, \$615.55; Rhode Island, \$0.40; Vermont, \$617.25.
 Purnell—Connecticut State, \$21.10; Connecticut Storrs, \$2,560.09; Illinois, \$640.62; Massachusetts, \$1.80; New York Cornell, \$393.06; New York State, \$0.06; North Dakota, \$3.29; Ohio, \$1,873.01; Rhode Island, \$1.35.
 Bankhead-Jones—Connecticut State, \$210.10; Connecticut Storrs, \$438.38; Hawaii, \$194.56; Illinois, \$86.35; Maryland, \$0.03; New York Cornell, \$18.62; North Dakota, \$0.25; Ohio, \$2,390.86; Rhode Island, \$0.04.
² Hatch, \$15,000 for each State, Alaska, Hawaii, and Puerto Rico. Adams, \$15,000 for each State, Hawaii, and Puerto Rico; \$7,500 for Alaska. Purnell, \$60,000 for each State, Hawaii, and Puerto Rico; \$20,000 for Alaska.

TABLE 3.—Expenditures and appropriations under the Hatch Act (Mar. 2, 1887) ¹ for the year ended June 30, 1946

Station	Expenditures											Unex- pended	Appro- priation
	Personal Services	Travel	Trans- portation of things	Com- muni- cation service	Rents and util- ity serv- ices	Printing and binding	Other contrac- tual services	Supplies and materials	Equip- ment	Lands and struc- tures (contrac- tual)	Contri- butions to retire- ment		
Alabama.....	\$13,535.30		\$2.46	\$43.50	\$93.50	\$100.81	\$119.16	\$504.01	\$601.26			\$15,000.00	\$15,000
Alaska.....	12,177.54	\$392.23	278.36	13.00	76.68		19.30	1,580.17	462.72			15,000.00	15,000
Arizona.....	14,091.28	104.25					62.16		742.31			15,000.00	15,000
Arkansas.....	8,999.15	316.91		107.71		1,790.16	58.39	2,700.14	440.71		\$210.00	14,623.17	15,000
California.....	15,000.00											15,000.00	15,000
Colorado.....	13,785.97	471.03		41.36	51.20		38.75	206.60			405.09	15,000.00	15,000
Connecticut.....													
State.....	6,860.00						633.85					7,493.85	7,500
Storrs.....	3,039.00	281.53	4.81	18.47	108.00	299.51	242.23	1,315.13	1,019.54			6,328.22	7,500
Delaware.....	9,759.06	594.36	23.48	1,556.89	90.14	1,604.12	29.45	856.21	486.29			15,000.00	15,000
Florida.....	15,000.00											15,000.00	15,000
Georgia.....	12,854.06	321.80		1.16		236.95	21.63	1,117.72	446.68			15,000.00	15,000
Hawaii.....	15,000.00											15,000.00	15,000
Idaho.....	8,623.93	1,722.69	12.34	151.91		1,113.85	101.18	829.54	2,444.56			15,000.00	15,000
Illinois.....	14,432.67										567.33	15,000.00	15,000
Indiana.....	15,000.00											15,000.00	15,000
Iowa.....	15,000.00											15,000.00	15,000
Kansas.....	14,216.27	461.90		107.70	18.75	29.41		165.97				15,000.00	15,000
Kentucky.....	13,940.00	169.23				890.77						15,000.00	15,000
Louisiana.....	13,829.13	78.67		3.59		218.84	139.90	729.87				15,000.00	15,000
Maine.....	10,423.04	875.15	93.10	594.69	853.42	934.19	259.18	904.42	62.81			15,000.00	15,000
Maryland.....	11,836.47	75.00	2.00					3,032.35	354.18			15,000.00	15,000
Massachusetts.....	13,210.43	364.36		4.50				270.04	1,150.67			15,000.00	15,000
Michigan.....	15,000.00											15,000.00	15,000
Minnesota.....	12,731.45						61.65	531.33	1,364.06		311.51	15,000.00	15,000
Mississippi.....	10,709.16	165.87	13.10	495.13	1.25	1,619.89	195.35	664.11	1,003.39			15,000.00	15,000
Missouri.....	14,600.70										399.30	15,000.00	15,000
Montana.....	10,672.38	116.50	2.88	412.88	303.06	875.87	96.39	2,009.84	510.20			15,000.00	15,000
Nebraska.....	15,000.00											15,000.00	15,000
Nevada.....	12,267.15		2.23	314.27	144.66	685.80	66.00	995.39	60.00		464.50	15,000.00	15,000

New Hampshire	10,974.14	350.84	332.79	514.40	700.00	540.42	320.77	557.48	709.16	15,000.00	-----	15,000
New Jersey	14,047.00	65.39	-----	6.00	-----	-----	214.05	547.11	120.45	15,000.00	-----	15,000
New Mexico	13,306.41	43.10	2.81	3.00	392.27	272.60	373.47	275.34	331.00	15,000.00	-----	15,000
New York:	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Cornell	10,253.26	-----	3.73	33.56	71.95	-----	1,224.24	1,110.49	782.12	13,479.35	20.65	13,500
State	1,454.14	-----	-----	-----	-----	-----	-----	-----	-----	1,454.14	45.86	1,500
North Carolina	12,653.85	394.24	12.03	86.89	35.00	631.25	216.26	723.42	247.06	15,000.00	-----	15,000
North Dakota	12,935.38	-----	-----	24.67	75.00	933.58	35.79	390.67	233.61	15,000.00	-----	15,000
Ohio	6,800.84	302.74	2.66	-----	672.76	-----	-----	6,077.83	995.00	14,851.83	148.17	15,000
Oklahoma	8,506.87	914.41	166.37	21.40	-----	13.57	829.14	2,808.97	1,735.27	15,000.00	-----	15,000
Oregon	12,562.95	144.53	9.04	17.55	170.00	765.72	1.57	1,270.64	58.00	15,000.00	-----	15,000
Pennsylvania	11,854.94	250.00	-----	-----	-----	2,567.25	-----	81.45	107.01	15,000.00	-----	15,000
Puerto Rico	10,526.03	654.71	15.76	11.40	-----	-----	46.76	2,350.87	1,394.61	15,000.00	-----	15,000
Rhode Island	10,998.08	284.49	4.64	399.40	-----	559.21	644.26	1,997.22	72.08	14,959.38	40.62	15,000
South Carolina	11,112.19	454.68	4.29	346.81	-----	903.43	131.25	1,637.03	410.32	15,000.00	-----	15,000
South Dakota	10,462.28	662.55	7.97	120.24	6.00	1,554.48	259.45	588.62	1,338.31	15,000.00	-----	15,000
Tennessee	13,062.36	-----	102.08	257.68	28.20	-----	159.40	742.56	647.82	15,000.00	-----	15,000
Texas	9,773.11	2,062.23	-----	225.66	-----	120.25	317.07	1,116.49	1,353.19	15,000.00	-----	15,000
Utah	13,941.78	13.83	1.17	-----	16.13	13.75	10.50	588.32	412.50	15,000.00	-----	15,000
Vermont	9,390.70	316.76	14.19	459.11	758.41	1,289.87	379.17	1,883.46	259.70	15,000.00	243.63	15,000
Virginia	14,254.13	-----	-----	28.00	24.84	-----	92.21	571.82	28.95	15,000.00	-----	15,000
Washington	13,922.65	158.32	-----	11.68	-----	-----	437.35	77.50	14.00	15,000.00	-----	15,000
West Virginia	13,166.00	166.23	26.02	-----	-----	120.63	152.81	1,345.31	23.00	15,000.00	-----	15,000
Wisconsin	11,488.46	62.04	-----	3.51	-----	164.91	-----	3,281.08	-----	15,000.00	-----	15,000
Wyoming	12,652.25	258.94	30.01	35.24	114.00	636.38	19.82	1,129.44	133.92	15,000.00	-----	15,000
Total	631,394.05	14,071.53	1,169.32	6,472.96	4,805.22	21,494.77	8,009.71	49,565.96	22,598.46	763,189.94	1,810.06	765,000

¹ Extended to Hawaii by act of May 16, 1928; to Alaska by act of Feb. 23, 1929; and to Puerto Rico by act of Mar. 4, 1931.

TABLE 4.—Expenditures and appropriations under the Adams Act (Mar. 16, 1906)¹ for the year ended June 30, 1946

Station	Expenditures										Unexpended	Appropriation
	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total expenditures	
Alabama	\$12,766.51	\$179.55	\$43.80	\$1.18	\$513.33	\$196.71	\$1,075.43	\$213.49			\$15,000.00	\$15,000
Alaska	7,086.62	59.65					217.10	136.63			7,500.00	7,500
Arizona	11,779.06			37.30		76.45	1,713.30	64.21			15,000.00	15,000
Arkansas	13,308.61	117.36	32.78			120.44	759.37	157.14		\$555.00	14,997.92	\$2.08
California	15,000.00										15,000.00	15,000
Colorado	12,676.90	353.02		22.72	345.92	230.46	829.95	264.82		276.21	15,000.00	15,000
Connecticut:												
State	7,500.00											
Storrs	7,400.00											7,500
Delaware	11,297.75	290.14	7.94		240.61	180.26	815.18	1,503.13	\$400.00		14,737.01	15,000
Florida	15,000.00										15,000.00	15,000
Georgia	11,314.27	5.30	3.00	1.57		2.24	2,644.70	1,028.92			15,000.00	15,000
Hawaii	15,000.00										15,000.00	15,000
Idaho	12,197.31	420.03	12.28	18.90	31.50	428.99	1,003.94	497.05	380.00		15,000.00	15,000
Illinois	14,479.47						7.25			513.28	15,000.00	15,000
Indiana	12,309.04					50.00	2,617.22				14,976.26	15,000
Iowa	15,000.00										15,000.00	15,000
Kansas	14,145.26					75.04	724.74	54.96			15,000.00	15,000
Kentucky	14,853.27		3.79				142.94				15,000.00	15,000
Louisiana	13,938.31	253.98		.62		62.11	589.98	155.00			15,000.00	15,000
Maine	14,067.93	164.46				15.34	688.84	63.43			15,000.00	15,000
Maryland	12,769.98	671.27	6.88			133.62	1,325.74	92.51			15,000.00	15,000
Massachusetts	15,000.00										15,000.00	15,000
Michigan	15,000.00										15,000.00	15,000
Minnesota	13,055.03	229.80				36.40	88.50	1,216.08		374.19	15,000.00	15,000
Mississippi	11,544.33	176.42	53.34	54.80	170.29	910.55	965.02	1,125.25			15,000.00	15,000
Missouri	9,993.25		204.49	.40	11.00	228.19	3,337.27	730.30	312.00	163.10	15,000.00	15,000
Montana	13,154.60	607.24	12.48	7.92	.75	65.53	826.99	324.49			15,000.00	15,000
Nebraska	15,000.00										15,000.00	15,000
Nevada	12,386.75	261.60	3.26	77.00		71.49	890.56	983.53		385.75	15,000.00	15,000

New Hampshire.....	13,684.45	60.92	8.45	3.36	80.00	58.29	463.69	640.84	15,000.00	-----	15,000
New Jersey.....	13,290.85	2.50	-----	-----	-----	46.80	1,235.05	424.80	15,000.00	-----	15,000
New Mexico.....	12,966.48	145.37	11.89	2.18	273.84	20.72	959.52	620.00	15,000.00	-----	15,000
New York:											
Cornell.....	10,682.33	2.00	-----	-----	-----	87.23	1,257.67	1,451.51	13,480.74	19.26	13,500
State.....	663.10	-----	-----	-----	-----	24.45	306.37	506.08	1,500.00	-----	1,500
North Carolina.....	12,839.84	374.04	12.95	16.71	-----	220.46	1,225.79	310.21	15,000.00	-----	15,000
North Dakota.....	13,835.60	14.26	1.63	4.72	-----	-----	569.38	249.91	14,999.95	-----	15,000
Ohio.....	12,676.00	-----	42.67	-----	-----	-----	750.56	768.89	14,238.12	761.88	15,000
Oklahoma.....	11,552.00	74.40	4.03	-----	-----	391.61	2,046.23	931.73	15,000.00	-----	15,000
Oregon.....	12,702.60	926.00	5.39	41.02	22.93	33.31	1,098.29	170.46	15,000.00	-----	15,000
Pennsylvania.....	15,000.00	-----	-----	-----	-----	-----	-----	-----	15,000.00	-----	15,000
Puerto Rico.....	13,050.48	345.26	-----	-----	9.00	521.53	811.69	262.06	15,000.00	-----	15,000
Rhode Island.....	14,001.06	18.53	1.72	-----	-----	65.94	651.19	212.85	14,948.29	51.71	15,000
South Carolina.....	12,825.05	149.54	1.40	150.86	53.98	64.71	380.65	1,384.81	15,000.00	-----	15,000
South Dakota.....	13,115.38	325.53	26.43	20.32	-----	141.60	922.70	448.74	15,000.00	-----	15,000
Tennessee.....	13,602.33	-----	43.25	-----	14.65	107.60	635.75	596.42	15,000.00	-----	15,000
Texas.....	14,766.37	-----	1.24	2.42	-----	38.20	133.77	38.00	15,000.00	-----	15,000
Utah.....	13,367.12	145.20	7.06	-----	-----	2.50	488.46	989.66	15,000.00	-----	15,000
Vermont.....	12,809.22	263.17	23.88	.86	37.36	74.45	937.50	426.34	15,000.00	39.00	15,000
Virginia.....	13,748.40	304.60	-----	-----	-----	176.00	680.20	90.80	15,000.00	-----	15,000
Washington.....	13,111.75	414.41	-----	1.75	-----	10.94	616.27	481.88	15,000.00	363.00	15,000
West Virginia.....	13,700.02	76.84	22.20	-----	-----	64.45	1,078.58	58.41	15,000.00	-----	15,000
Wisconsin.....	10,146.00	-----	130.70	-----	-----	-----	4,723.30	-----	15,000.00	-----	15,000
Wyoming.....	12,345.56	197.50	3.08	30.00	-----	34.11	1,833.97	555.69	15,000.00	-----	15,000
Total.....	669,496.22	8,923.68	731.01	505.67	1,805.16	5,068.72	45,070.60	20,233.03	756,278.29	1,221.71	757,500

i Extended to Hawaii by act of May 16, 1928; to Puerto Rico by act of Mar. 4, 1931; and to Alaska by act of June 30, 1936.

TABLE 5.—Expenditures and appropriations under the Furnell Act (Feb. 24, 1925)¹ for the year ended June 30, 1946

Station	Expenditures											Unex- pended	Appro- priation
	Personal services	Travel	Trans- portation of things	Com- muni- cation service	Rents and utility services	Printing and binding	Other contrac- tual services	Supplies and materials	Equip- ment	Lands and structures (contrac- tual)	Contribu- tions to retirement		
Alabama	\$48,951.02	\$475.88	\$120.89	\$182.77	\$1,587.06	\$303.32	\$594.03	\$5,659.75	\$2,175.28			\$60,000.00	\$60,000
Alaska	18,271.37	555.47	284.31	20				820.90	67.12			20,000.00	20,000
Arizona	43,187.61	2,012.80	34.69	67.84	210.87	1,596.15	278.24	8,912.68	3,699.58			60,000.00	60,000
Arkansas	40,705.86	1,133.48	9.75	2.31	203.37	2.00	1,095.90	3,755.34	9,761.71	\$2,298.59	\$923.32	59,891.63	60,000
California	60,000.00											60,000.00	60,000
Colorado	44,112.89	2,012.44	13.24	101.09	1,276.88	35.39	1,174.95	5,456.18	4,007.62	698.00	1,111.32	60,000.00	60,000
Connecticut:													
State	27,096.95	337.96				23.50	536.50	1,332.37	223.63			29,550.91	30,000
Storrs	24,820.43	645.82	1.09	16.04		7.41	68.20	1,626.94	924.63			28,119.56	30,000
Delaware	43,526.63	2,750.86	16.53	14.19	386.44	308.00	973.99	9,292.62	1,276.32			58,545.58	60,000
Florida	55,257.33	368.70		7.12	4.05		34.16	568.26	3,760.38			60,000.00	60,000
Georgia	38,850.20	2,048.50	97.69	1.43	57.00	1,205.05	1,946.51	10,952.06	4,841.56			60,000.00	60,000
Hawaii	57,580.17							220.89	2,198.94			60,000.00	60,000
Idaho	51,227.38	2,092.62	78.47	94.23	90.88		773.85	3,991.82	1,650.75			60,000.00	60,000
Illinois	53,362.79	1,914.26	25.42			891.52	1,367.02	521.37	602.81		1,314.81	60,000.00	60,000
Indiana	49,423.55	2,035.76		11.85			205.55	3,542.29	988.91			56,207.91	60,000
Iowa	60,000.00											3,792.09	60,000
Kansas	56,415.05	450.02	38.99		8.24	121.18	262.30	2,392.21	312.01			60,000.00	60,000
Kentucky	54,252.35	2,017.75	4.94	70.08		3,137.48	157.29	340.86	19.25			60,000.00	60,000
Louisiana	49,280.17	2,803.47	119.87	64.48	165.31	354.75	504.32	4,165.88	2,541.75			60,000.00	60,000
Maine	47,232.16	911.45	37.41	4.94	1,018.20	421.54	810.50	8,712.82	850.98			60,000.00	60,000
Maryland	45,664.96	1,958.78	18.84	16.00		557.97	588.54	9,873.80	1,296.64			59,975.53	60,000
Massachusetts	50,832.30	1,793.57				194.97	90.40	4,322.35	2,766.41			60,000.00	60,000
Michigan	55,836.50					11.43		644.60	3,507.47			60,000.00	60,000
Minnesota	50,011.79	1,383.90	126.02	33.00		577.50	1,041.57	1,449.53	4,561.92		814.77	60,000.00	60,000
Mississippi	46,549.79	1,621.39	175.81	372.18	555.75	2,426.04	968.63	3,906.35	3,299.19	124.87		60,000.00	60,000
Missouri	43,972.73	979.52	84.04	100.79	106.13	614.91	832.27	10,371.16	2,384.03		554.42	60,000.00	60,000
Montana	50,401.75	1,760.39	54.11	83.83	742.53	648.61	807.38	3,558.73	1,965.67			60,000.00	60,000
Nebraska	51,899.92	1,276.12	7.13	62.18		252.33	515.65	2,472.43	3,514.24			60,000.00	60,000
Nevada	51,308.76	1,218.47	69.42	387.36	558.73	51.61	399.29	4,441.68	348.18		1,216.50	60,000.00	60,000

New Hampshire	51,088.15	2,124.60	104.54	78.23	147.46	1,192.10	926.07	2,888.00	1,480.85	60,000.00
New Jersey	51,766.06	859.02	1.98	1.00	96.00	3.50	799.87	2,554.36	3,917.61	60,000.00
New Mexico	46,372.56	1,392.27	42.03	85.15	1,698.78	1,537.42	1,008.71	5,578.28	2,281.60	60,000.00
New York	44,088.71	1,015.21	20.05	52.40	1,555.20	33.90	1,462.55	3,140.95	2,266.54	54,000.00
Cornell State	5,152.51			.71				191.28	642.70	5,987.20
North Carolina	46,179.38	3,560.28	15.01	299.58	686.32	234.06	649.44	5,929.59	2,446.34	60,000.00
North Dakota	50,567.22	609.26	168.33	41.88	79.31	274.71	227.91	4,092.24	2,693.18	60,000.00
Ohio	50,952.34	1,140.49	20.05				152.56	4,764.51	2,700.70	59,730.65
Oklahoma	46,673.05	493.60	113.70		53.75	315.73	2,100.40	8,893.48	1,092.29	269.35
Oregon	49,710.88	2,861.77	37.92	677.77	131.57	522.94	2,105.02	2,747.82	1,203.71	60,000.00
Pennsylvania	54,672.90	681.83	6.37	18.00			237.94	3,477.99	904.97	60,000.00
Puerto Rico	43,058.89	1,797.63	7.30		30.00	1,472.10	572.01	3,845.59	9,216.48	60,000.00
Rhode Island	54,027.33	819.74	34.34			451.32	126.36	3,190.09	1,298.98	59,948.16
South Carolina	44,447.28	2,664.28	213.17	477.08	1,373.27	1,712.87	841.22	3,988.11	4,282.72	60,000.00
South Dakota	48,556.29	3,287.30	77.44	133.26	281.00	20.00	660.32	4,112.65	2,871.74	60,000.00
Tennessee	54,550.39	453.24	109.67	30.57	278.86		479.88	2,558.85	1,538.54	60,000.00
Texas	51,841.52	1,935.28	62.24	305.22	19.49	3.48	572.06	3,517.09	1,584.86	60,000.00
Utah	49,020.05	3,387.70	115.04	21.00	89.00	622.80	482.00	3,855.85	1,702.91	60,000.00
Vermont	47,287.37	1,618.34	59.93	47.17	105.57	661.66	747.92	2,028.44	5,871.99	60,000.00
Virginia	49,261.80	1,225.02	16.46		1,436.50	1,232.03	443.16	2,610.36	3,754.67	60,000.00
Washington	52,626.81	2,480.58	207.17	91.79		1,232.11	215.04	1,284.10	1,118.77	60,000.00
West Virginia	53,249.00	688.31	8.01		364.30	232.11	146.07	4,421.14	891.06	60,000.00
Wisconsin	56,172.89	912.51	5.95	12.06	11.05		65.88	2,819.95		60,000.00
Wyoming	52,587.12	1,811.26	27.04	44.47	31.00	311.74	225.57	3,006.36	1,955.44	60,000.00
Total	2,523,921.91	74,379.50	2,892.40	4,061.25	15,459.88	25,877.87	31,275.30	198,752.95	121,269.00	3,020,000.00
							4,570.37	9,102.21	3,011,562.64	8,437.36

1 Extended to Hawaii by act of May 16, 1928; to Alaska by act of Feb. 23, 1929; and to Puerto Rico by act of Mar. 4, 1931.

TABLE 6.—Expenditures and appropriations under the Bankhead-Jones act (June 29, 1935) for the year ended June 30, 1946

Station	Expenditures											Unex- pended	Appro- priation	
	Personal services	Travel	Trans- portation of things	Com- muni- cation service	Rents and utility services	Printing and binding	Other contract- ual services	Supplies and materials	Equip- ment	Lands and structures (contract- ual)	Contribu- tions to retirement			Total ex- penditures
Alabama.....	\$68,197.85	\$1,169.44	\$332.25	\$177.77	\$1,450.13	\$141.41	\$3,829.74	\$10,680.29	\$3,392.92	\$52.16	---	\$89,423.96	\$89,423.96	---
Alaska.....	2,195.36	---	---	---	---	---	---	---	244.80	---	---	2,440.16	2,440.16	---
Arizona.....	3,246.50	894.65	74.00	138.89	---	233.03	217.19	1,981.20	1,606.78	---	---	14,392.24	14,392.24	---
Arkansas.....	49,620.62	985.43	14.18	2.36	1,330.14	346.26	959.92	3,475.28	9,396.11	2,284.44	\$712.24	69,135.98	69,135.98	\$12.02
California.....	88,677.97	40.15	---	---	---	---	---	---	---	---	---	88,718.12	88,718.12	---
Colorado.....	20,011.67	1,042.31	---	95.13	437.41	---	364.68	1,331.93	478.24	---	481.11	24,243.48	24,243.48	---
Connecticut: State.....	9,342.16	69.55	46.80	---	---	---	58.73	969.85	1,010.22	---	---	11,497.31	11,497.31	694.17
Storrs.....	7,986.53	73.25	---	---	---	---	72.23	1,117.02	1,008.26	---	---	10,257.29	10,257.29	1,934.19
Delaware.....	4,182.55	10.95	---	---	---	128.50	---	1,172.73	127.71	---	---	5,622.44	5,622.44	---
Florida.....	27,890.69	297.58	40.64	6.21	---	---	1,250.47	4,805.28	3,419.81	---	---	37,680.68	37,680.68	---
Georgia.....	68,337.96	1,691.88	102.62	1.63	663.03	1,257.30	2,032.01	15,477.24	4,936.21	---	---	94,499.88	94,499.88	---
Hawaii.....	9,727.90	---	---	---	---	---	---	---	---	---	---	9,727.90	9,727.90	02
Idaho.....	9,950.54	689.75	4.90	14.87	7.30	236.91	47.54	3,407.93	1,045.10	---	---	15,404.84	15,404.84	---
Illinois.....	79,167.48	2,175.84	60.60	61.47	30.98	639.07	2,197.23	5,939.80	842.78	---	2,686.47	93,841.72	93,841.72	---
Indiana.....	52,022.09	1,012.67	253.78	15.28	18.75	---	291.21	6,892.82	6,263.40	232.50	---	67,002.50	67,002.50	1,139.70
Iowa.....	69,803.56	---	---	---	---	---	---	---	---	---	---	69,803.56	69,803.56	---
Kansas.....	48,649.29	282.15	---	---	6.00	25.65	266.00	3,346.92	1,038.75	---	---	53,614.76	53,614.76	---
Kentucky.....	1,013.58	1,013.58	36.97	2.25	---	1,334.21	337.50	1,433.62	1,891.55	---	---	88,327.80	88,327.80	---
Louisiana.....	49,502.99	3,257.55	114.01	167.54	27.78	236.84	704.66	3,585.31	3,614.72	---	---	61,211.40	61,211.40	---
Maine.....	18,500.77	1,698.69	---	22.29	65.20	529.95	161.26	1,034.73	395.23	---	---	22,408.12	22,408.12	---
Maryland.....	22,343.73	1,067.55	21.00	---	134.43	73.50	308.35	8,358.68	474.16	---	---	32,781.40	32,781.40	---
Massachusetts.....	76,311.29	137.55	---	---	---	---	1.00	683.29	248.50	---	---	20,231.16	20,231.16	---
Michigan.....	76,311.29	137.55	---	---	---	---	---	---	---	---	---	79,697.20	79,697.20	---
Minnesota.....	46,930.43	2,172.76	147.64	98.50	333.64	518.08	785.79	5,068.80	5,297.38	---	688.46	62,041.48	62,041.48	---
Mississippi.....	57,108.14	1,744.18	454.17	393.19	629.76	164.71	856.92	12,930.39	3,413.66	855.59	---	78,610.71	78,610.71	01
Missouri.....	55,734.18	981.83	142.69	278.71	608.57	1,037.52	1,088.74	18,263.19	3,103.23	1,118.97	692.09	83,175.72	83,175.72	---
Montana.....	15,073.37	---	39.66	16.10	---	34.05	---	1,086.34	371.86	---	---	16,687.32	16,687.32	---
Nebraska.....	33,970.91	917.23	99.22	28	100.00	181.43	15.22	5,612.03	608.84	---	---	41,505.16	41,505.16	---
Nevada.....	2,587.71	181.45	85	4.33	---	---	---	63.18	---	---	120.00	2,962.62	2,962.62	---

TABLE 7.—Expenditures from non-Federal funds for the year ended June 30, 1946

Station	Personal services	Travel	Transportation of things	Communication service	Rents and utility services	Printing and binding	Other contractual services	Supplies and materials	Equipment	Lands and structures (contractual)	Contributions to retirement	Total	Unexpended balances
Alabama.....	\$216,340.68	\$12,918.29	\$5,948.00	\$2,556.32	\$6,303.14	\$678.41	\$103,253.92	\$91,522.42	\$24,616.35	\$8,189.89	-----	\$472,327.42	\$242,891.62
Alaska.....	12,889.10	711.74	351.89	334.47	1,372.51	463.86	2,072.43	8,508.30	4,284.40	1,073.82	-----	35,342.52	11,192.42
Arizona.....	107,090.28	4,398.88	3,388.88	1,505.36	2,687.13	4,848.17	5,255.33	11,980.08	29,988.44	-----	-----	167,783.46	15,499.64
Arkansas.....	125,757.12	12,129.73	150.27	1,131.44	4,425.43	6.00	2,478.86	28,252.68	11,020.84	11,179.89	\$1,082.64	197,624.90	45,264.24
California.....	1,349,122.06	37,612.46	4,066.86	18,506.74	33,254.10	35,950.30	88,089.18	136,590.39	55,313.03	-----	-----	1,758,805.12	208,026.90
Colorado.....	132,390.22	5,340.46	1,888.53	1,878.42	4,913.14	4,433.68	17,486.50	61,717.14	37,844.47	8,907.25	1,656.74	278,456.55	106,737.11
Connecticut.....	145,459.62	1,221.57	114.66	1,680.20	3,802.21	69.28	2,503.64	15,015.98	5,579.62	-----	-----	175,456.78	36,733.20
State.....	61,386.99	456.33	96.15	221.16	-----	-----	962.28	10,835.12	634.33	-----	-----	74,622.36	-----
Storrs.....	58,102.67	3,006.21	853.29	638.84	2,661.50	696.44	1,992.57	41,212.66	7,863.11	16,115.39	-----	132,874.68	59,200.46
Delaware.....	644,606.17	36,764.21	5,331.04	6,637.18	16,074.64	9,482.24	57,153.50	190,754.66	106,663.76	22,400.00	-----	1,095,887.40	325,025.81
Florida.....	130,462.25	3,485.81	1,418.75	1,681.98	5,324.00	2,125.65	9,781.04	49,044.77	6,696.17	20,100.00	-----	230,120.42	94,137.47
Georgia.....	204,114.58	3,520.58	909.00	1,451.91	4,031.57	855.61	10,673.91	31,792.28	18,903.64	-----	-----	276,253.08	1,949.52
Hawaii.....	45,649.63	1,564.23	400.00	600.00	800.00	-----	1,000.00	15,700.00	5,283.33	5,000.00	-----	75,597.19	24,270.20
Idaho.....	568,890.32	28,500.00	-----	10,050.00	-----	20,000.00	-----	147,530.14	27,422.61	-----	-----	892,393.07	-----
Illinois.....	425,438.23	16,298.47	5,898.99	6,336.77	9,644.28	5,797.93	35,416.03	219,950.33	67,673.53	27,061.14	-----	819,515.70	548,092.30
Iowa.....	350,350.35	15,729.39	1,887.39	3,596.81	2,854.26	9,868.08	-----	166,866.29	48,698.01	-----	-----	599,760.58	187,384.29
Kansas.....	187,410.02	6,660.63	2,809.00	1,699.81	6,893.10	846.47	10,702.29	68,279.69	24,833.03	887.74	-----	311,021.78	250,610.00
Kentucky.....	210,848.76	9,261.80	1,121.27	2,038.81	810.55	21,870.81	14,957.16	64,072.95	21,358.08	-----	-----	346,340.79	-----
Louisiana.....	278,096.42	19,183.30	646.34	2,856.70	5,359.58	3,496.43	11,883.03	39,760.69	21,738.18	-----	1,185.83	334,007.50	-----
Maine.....	109,866.06	9,542.59	3,323.16	854.30	16,568.34	3,167.72	12,512.09	24,241.55	8,808.38	4,110.77	7,805.92	200,800.88	24,867.21
Maryland.....	92,239.42	3,075.86	727.37	1,166.77	1,867.98	851.00	8,372.86	49,499.25	18,405.76	-----	-----	176,066.27	56,378.84
Massachusetts.....	184,277.85	3,447.04	619.64	2,187.03	1,227.36	1,531.22	2,050.33	18,775.17	6,680.53	257.50	-----	221,003.67	30,086.34
Michigan.....	279,898.60	15,650.26	939.21	1,042.86	2,620.47	17,271.72	10,138.96	44,177.11	1,909.37	1,909.37	-----	395,392.42	-----
Minnesota.....	418,917.68	8,105.71	1,965.16	4,736.85	7,622.76	7,600.13	42,057.81	89,673.96	26,857.39	7,991.02	-----	615,528.47	-----
Mississippi.....	240,217.98	8,937.63	2,140.55	4,042.38	8,380.40	15,295.82	16,537.24	48,630.17	52,054.92	15,434.20	-----	411,671.29	182,103.99
Missouri.....	115,786.04	5,616.35	1,129.31	1,914.45	6,870.85	7,490.71	8,562.03	66,322.59	12,323.14	2,606.31	-----	228,621.81	143,895.94
Montana.....	171,267.76	8,423.88	1,175.36	2,561.09	8,052.70	7,758.85	13,898.68	66,650.42	33,070.87	8,345.58	2,000.00	316,781.19	135,828.19
Nebraska.....	66,807.07	7,924.55	2,433.93	1,350.47	11,278.50	3,849.47	11,021.44	212,884.93	51,505.39	2,197.88	-----	370,933.63	-----
Nevada.....	4,678.79	1,662.96	1,045.39	550.47	2,874.66	387.15	1,692.95	6,613.56	7,313.64	43.30	-----	26,862.87	9,809.49

New Hampshire.....	8, 803.26	340.37	7.50	17.98	66.44	41.42	1, 831.20	1, 103.77	599.46	12, 211.94	32, 605.44
New Jersey.....	518, 086.74	9, 889.48	963.33	-----	7, 418.98	12, 231.42	99, 817.40	4, 016.26	-----	675, 608.19	9, 637.56
New Mexico.....	33, 718.48	1, 258.86	493.82	304.92	819.99	9, 901.95	15, 023.60	8, 432.13	-----	72, 783.86	107, 242.04
New York:											
Cornell.....	782, 076.62	16, 016.58	2, 820.31	8, 887.39	8, 760.58	30, 019.07	121, 736.46	32, 448.22	1, 838.27	1, 064, 052.96	-----
State.....	401, 921.98	7, 484.98	1, 745.81	3, 819.09	6, 214.60	11, 840.59	46, 879.59	11, 541.65	-----	504, 179.53	-----
North Carolina.....	212, 017.35	10, 497.14	855.35	3, 392.00	3, 614.36	12, 576.11	39, 188.79	37, 576.60	23, 989.85	348, 028.30	19, 454.84
North Dakota.....	33, 909.87	3, 101.27	609.36	1, 052.13	1, 917.68	31, 694.92	30, 374.12	24, 775.36	20, 125.12	209, 611.30	52, 989.87
Ohio.....	420, 238.36	6, 973.27	4, 060.71	2, 626.76	-----	-----	153, 581.36	46, 190.85	52, 312.14	686, 003.45	696, 317.54
Oklahoma.....	283, 138.05	11, 234.85	3, 214.50	1, 971.83	2, 417.74	18, 614.12	117, 436.92	35, 652.70	14, 165.88	498, 306.98	232, 780.48
Oregon.....	379, 602.08	14, 487.93	2, 540.54	4, 527.19	4, 251.09	26, 117.36	70, 078.57	34, 036.88	350.50	548, 574.79	-----
Pennsylvania.....	286, 349.11	9, 143.32	997.35	1, 170.39	2, 342.60	38, 646.37	60, 250.74	18, 356.84	6, 331.41	428, 446.59	16, 977.48
Puerto Rico.....	233, 118.12	9, 286.26	671.64	1, 257.66	383.37	740.40	47, 117.00	24, 102.11	2, 461.17	324, 870.33	201, 600.18
Rhode Island.....	17, 480.23	1, 013.69	64.47	198.71	599.98	437.09	8, 780.45	1, 928.83	300.00	31, 244.57	15, 803.67
South Carolina.....	232, 403.31	5, 422.49	4, 849.86	2, 558.08	2, 253.48	28, 307.11	152, 289.04	58, 315.68	40, 634.06	532, 293.21	148, 490.25
South Dakota.....	52, 092.30	4, 061.16	364.14	249.31	262.30	2, 074.20	38, 082.30	7, 112.60	-----	104, 762.29	57, 590.98
Tennessee.....	108, 014.22	1, 835.73	1, 512.28	1, 112.40	2, 901.29	8, 699.60	43, 981.41	21, 832.79	13, 238.80	205, 403.06	-----
Texas.....	542, 123.07	12, 113.84	2, 756.19	3, 913.19	3, 358.16	29, 517.92	211, 234.32	91, 578.63	5, 249.65	978, 810.70	560, 470.49
Utah.....	70, 887.20	7, 196.05	336.79	1, 728.11	5, 096.71	12, 238.66	16, 153.91	7, 815.09	1, 717.59	140, 129.42	79, 706.18
Vermont.....	13, 978.20	244.49	214.49	324.81	2, 024.96	2, 372.51	2, 849.66	2, 614.90	235.86	26, 190.51	5, 652.95
Virginia.....	189, 550.13	21, 445.08	1, 642.82	2, 577.47	7, 407.25	11, 605.62	29, 785.32	28, 114.29	117.00	298, 494.75	-----
Washington.....	350, 972.41	18, 058.41	1, 479.07	3, 242.99	5, 645.98	12, 399.25	80, 852.54	38, 282.10	7, 891.74	531, 191.18	-----
West Virginia.....	77, 881.61	1, 887.80	781.70	837.14	875.19	5, 369.73	48, 431.38	13, 527.07	-----	154, 782.39	57, 523.70
Wisconsin.....	745, 650.00	23, 682.00	4, 550.00	1, 916.00	6, 892.00	50, 730.00	195, 608.00	58, 327.00	-----	1, 093, 855.00	-----
Wyoming.....	51, 170.55	2, 346.95	1, 200.00	1, 045.75	30.54	3, 535.52	40, 443.23	15, 552.15	-----	118, 994.50	42, 187.57
Total.....	13, 043, 535.97	490, 267.55	92, 059.42	134, 630.90	255, 641.45	861, 917.00	3, 697, 962.59	1, 388, 266.91	421, 177.08	20, 786, 854.20	5, 071, 966.40

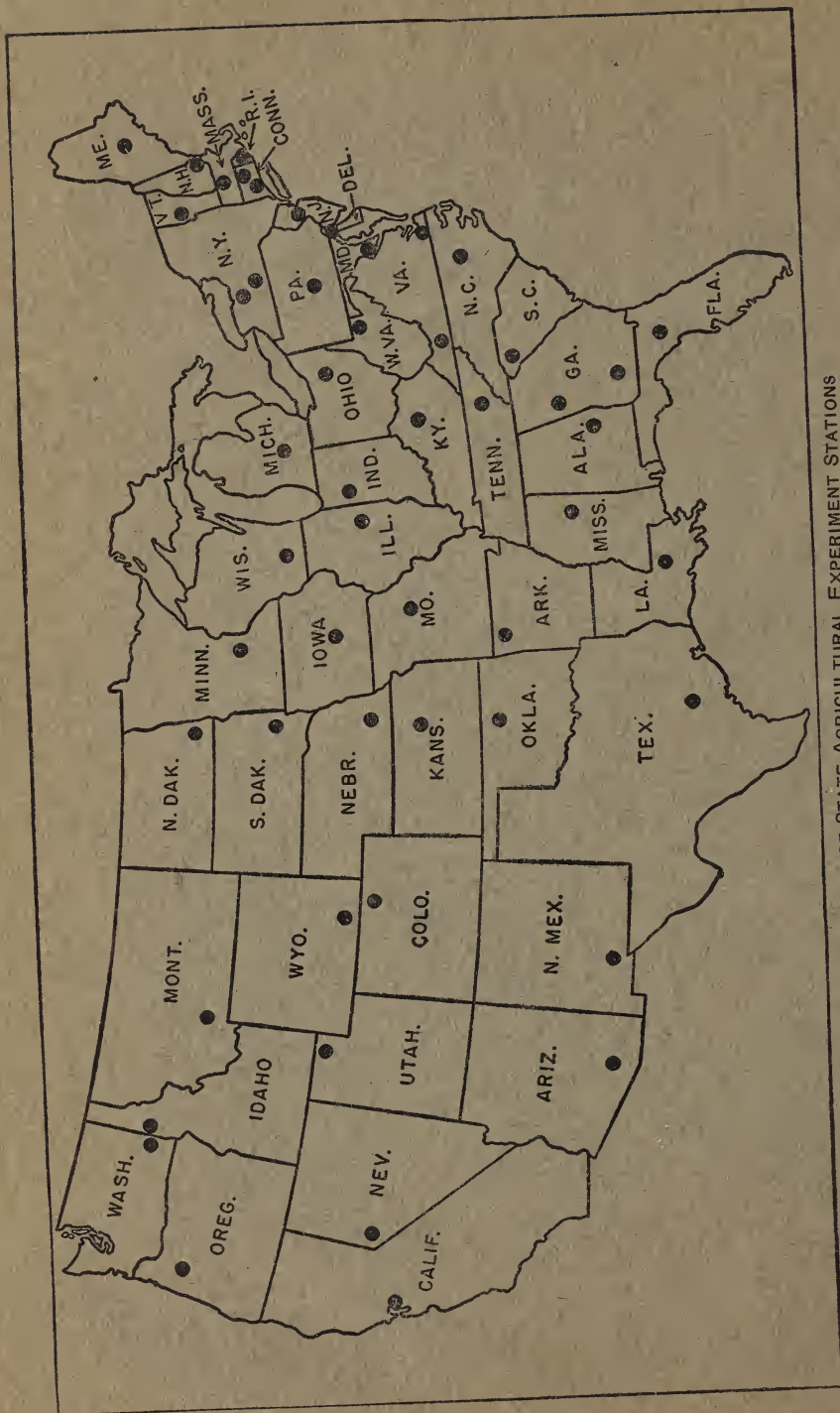
TABLE 8.—*Disbursements from the U. S. Treasury to the States and Territories and Puerto Rico for agricultural experiment stations under the Hatch Act (Mar. 2, 1887), Adams Act (Mar. 16, 1906), Purnell Act (Feb. 24, 1925), Bankhead-Jones Act (June 29, 1935), and supplementary acts*

State or Territory	Hatch Act 1888-1946	Adams Act 1906-46	Purnell Act 1926-46	Bankhead- Jones Act 1936-46
Alabama.....	\$884,199.34	\$579,966.80	\$1,159,903.19	\$781,995.59
Alaska.....	225,000.00	67,500.00	60,000.00	21,081.66
Arizona.....	849,467.73	584,995.61	1,159,986.80	121,881.58
Arkansas.....	883,127.12	584,900.00	1,158,772.76	603,524.58
California.....	885,000.00	584,926.84	1,160,000.00	704,788.75
Colorado.....	884,718.82	583,638.93	1,160,000.00	212,102.77
Connecticut.....	883,024.95	585,000.00	1,153,210.19	202,785.74
Dakota Territory.....	56,250.00			
Delaware.....	883,258.28	578,704.30	1,153,139.91	48,243.29
Florida.....	884,966.06	584,996.06	1,156,523.74	311,566.49
Georgia.....	880,593.43	572,092.87	1,160,000.00	827,504.34
Hawaii.....	274,919.17	206,940.95	386,561.41	86,469.46
Idaho.....	809,824.13	580,842.22	1,160,000.00	132,302.90
Illinois.....	878,435.51	584,545.99	1,151,005.43	814,609.79
Indiana.....	884,901.19	579,384.45	1,156,007.26	591,917.87
Iowa.....	885,000.00	585,000.00	1,157,965.17	612,961.17
Kansas.....	884,995.00	585,000.00	1,160,000.00	472,791.55
Kentucky.....	884,996.57	585,000.00	1,160,000.00	759,815.00
Louisiana.....	885,000.00	585,000.00	1,160,000.00	528,431.40
Maine.....	884,999.62	585,000.00	1,160,000.00	195,704.96
Maryland.....	884,967.40	584,236.48	1,159,296.98	278,728.60
Massachusetts.....	884,617.70	585,000.00	1,157,691.78	174,477.97
Michigan.....	884,676.10	581,341.60	1,158,393.18	666,947.90
Minnesota.....	884,917.78	584,345.74	1,160,000.00	539,607.31
Mississippi.....	885,000.00	585,000.00	1,160,000.00	687,066.20
Missouri.....	880,097.24	584,999.90	1,160,000.00	727,188.36
Montana.....	795,000.00	582,417.04	1,160,000.00	146,526.29
Nebraska.....	884,932.16	585,000.00	1,159,995.00	366,259.18
Nevada.....	883,331.08	581,145.10	1,160,000.00	24,666.38
New Hampshire.....	884,250.00	585,000.00	1,160,000.00	79,808.71
New Jersey.....	884,959.97	584,392.06	1,160,000.00	292,457.19
New Mexico.....	849,509.05	585,000.00	1,160,000.00	133,994.10
New York.....	884,730.46	583,973.69	1,158,190.74	873,028.75
North Carolina.....	885,000.00	585,000.00	1,160,000.00	988,265.82
North Dakota.....	841,491.45	584,589.62	1,159,733.98	232,980.24
Ohio.....	885,000.00	580,020.68	1,149,529.81	878,005.48
Oklahoma.....	816,919.88	572,842.65	1,159,887.70	646,176.40
Oregon.....	870,156.64	580,000.00	1,160,000.00	204,119.93
Pennsylvania.....	884,967.43	584,995.41	1,160,000.00	1,277,155.77
Puerto Rico.....	179,638.71	168,339.74	275,913.48	471,952.21
Rhode Island.....	884,775.04	579,331.40	1,158,830.42	22,181.01
South Carolina.....	884,541.37	583,360.12	1,160,000.00	562,363.60
South Dakota.....	828,250.00	580,000.00	1,160,000.00	230,704.40
Tennessee.....	885,000.00	585,000.00	1,160,000.00	719,287.72
Texas.....	885,000.00	582,592.26	1,160,000.00	1,412,218.66
Utah.....	850,000.00	584,821.94	1,160,000.00	99,305.20
Vermont.....	884,072.14	580,043.71	1,158,798.56	97,718.98
Virginia.....	883,766.58	583,544.94	1,159,974.86	665,777.02
Washington.....	823,414.48	581,080.11	1,160,000.00	298,175.68
West Virginia.....	884,804.16	581,263.82	1,159,942.89	519,384.56
Wisconsin.....	885,000.00	585,000.00	1,160,000.00	569,671.41
Wyoming.....	840,000.00	583,850.59	1,160,000.00	63,905.42
Total.....	42,605,463.75	28,420,963.62	56,349,255.24	22,980,486.34

ADDRESS LIST OF AGRICULTURAL EXPERIMENT STATIONS

- ALABAMA.—*Auburn*, M. J. Funchess, Director.
 ALASKA.—*College*, L. T. Oldroyd, Director.
 ARIZONA.—*Tucson*, P. S. Burgess, Director.
 ARKANSAS.—*Fayetteville*, L. S. Ellis, Director.
 CALIFORNIA.—*Berkeley 4*, C. B. Hutchison, Director.
 COLORADO.—*Fort Collins*, H. J. Henney, Director.
 CONNECTICUT.—*New Haven 4*, W. L. Slate, Director; *Storrs*, W. B. Young, Director.
 DELAWARE.—*Newark*, G. L. Schuster, Director.
 FLORIDA.—*Gainesville*, Harold Mowry, Director.
 GEORGIA.—*Experiment*, H. P. Stuckey, Director.
 HAWAII.—*Honolulu 10*, J. H. Beaumont, Director.
 IDAHO.—*Moscow*, D. R. Theophilus, Director.
 ILLINOIS.—*Urbana*, H. P. Rusk, Director.
 INDIANA.—*La Fayette*, H. J. Reed, Director.
 IOWA.—*Ames*, R. E. Buchanan, Director.
 KANSAS.—*Manhattan*, R. I. Throckmorton, Director.
 KENTUCKY.—*Lexington 29*, T. P. Cooper, Director.
 LOUISIANA.—*University Station, Baton Rouge 3*, W. G. Taggart, Director.
 MAINE.—*Orono*, Fred Griffie, Director.
 MARYLAND.—*College Park*, W. B. Kemp, Director.
 MASSACHUSETTS.—*Amherst*, F. J. Sievers, Director.
 MICHIGAN.—*East Lansing*, V. R. Gardner, Director.
 MINNESOTA.—*University Farm, St. Paul 1*, C. H. Bailey, Director.
 MISSISSIPPI.—*State College*, Russell Coleman, Acting Director.
 MISSOURI.—*Columbia*, E. A. Trowbridge, Director.
 MONTANA.—*Bozeman*, Clyde McKee, Director.
 NEBRASKA.—*Lincoln 1*, W. W. Burr, Director.
 NEVADA.—*Reno*, C. E. Fleming.
 NEW HAMPSHIRE.—*Durham*, M. G. Eastman, Director.
 NEW JERSEY.—*New Brunswick*, W. H. Martin, Director.
 NEW MEXICO.—*State College*, A. S. Curry, Acting Director.
 NEW YORK.—*Geneva* (State Station), A. J. Heinicke, Director; *Ithaca* (Cornell Station), C. E. F. Guterman, Director.
 NORTH CAROLINA.—*State College Station, Raleigh*, L. D. Baver, Director.
 NORTH DAKOTA.—*State College Station, Fargo*, H. L. Walster, Director.
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 PUERTO RICO.—*Mayaguez* (Federal Station), K. A. Bartlett, Director; *Rio Piedras* (University Station), Arturo Roque, Director.
 RHODE ISLAND.—*Kingston*, M. H. Campbell, Director.
 SOUTH CAROLINA.—*Clemson*, H. P. Cooper, Director.
 SOUTH DAKOTA.—*Brookings*, I. B. Johnson, Director.
 TENNESSEE.—*Knoxville*, C. E. Brehm, Director.
 TEXAS.—*College Station*, R. D. Lewis, Director.
 UTAH.—*Logan*, R. H. Walker, Director.
 VERMONT.—*Burlington*, J. E. Carrigan, Director.
 VIRGINIA.—*Blacksburg*, H. N. Young, Director.
 WASHINGTON.—*Pullman*, M. T. Buchanan, Director.
 WEST VIRGINIA.—*Morgantown*, C. R. Orton, Director.
 WISCONSIN.—*Madison 6*, I. L. Baldwin, Director.
 WYOMING.—*Laramie*, J. A. Hill, Director.

NOTE.—The full official titles, locations, and personnel of the agricultural experiment stations will be found in the list of Workers in Subjects Pertaining to Agriculture in Land-Grant Colleges and Experiment Stations, published annually by the United States Department of Agriculture.



HEADQUARTERS OF STATE AGRICULTURAL EXPERIMENT STATIONS